DoD EPA DOE SERDP
Strategic Environmental Research and Development Program

Improving Mission Readiness Through Environmental Research

ANNUAL REPORT TO CONGRESS

FISCAL YEAR 1998

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March 1999

SERDP
Strategic Environmental Research and Development Program

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ANNUAL REPORT TO CONGRESS—FISCAL YEAR 1998

FROM THE
STRATEGIC ENVIRONMENTAL RESEARCH AND DEVELOPMENT PROGRAM

March 1999

PREFACE

The Strategic Environmental Research and Development Program (SERDP) was established by Title 10 U.S.C. §§2901-2904. SERDP addresses environmental matters of concern to the Department of Defense and the Department of Energy. It is a Department of Defense program planned, managed, and executed in full partnership with the Department of Energy and the Environmental Protection Agency with participation by numerous other Federal and non-Federal organizations.

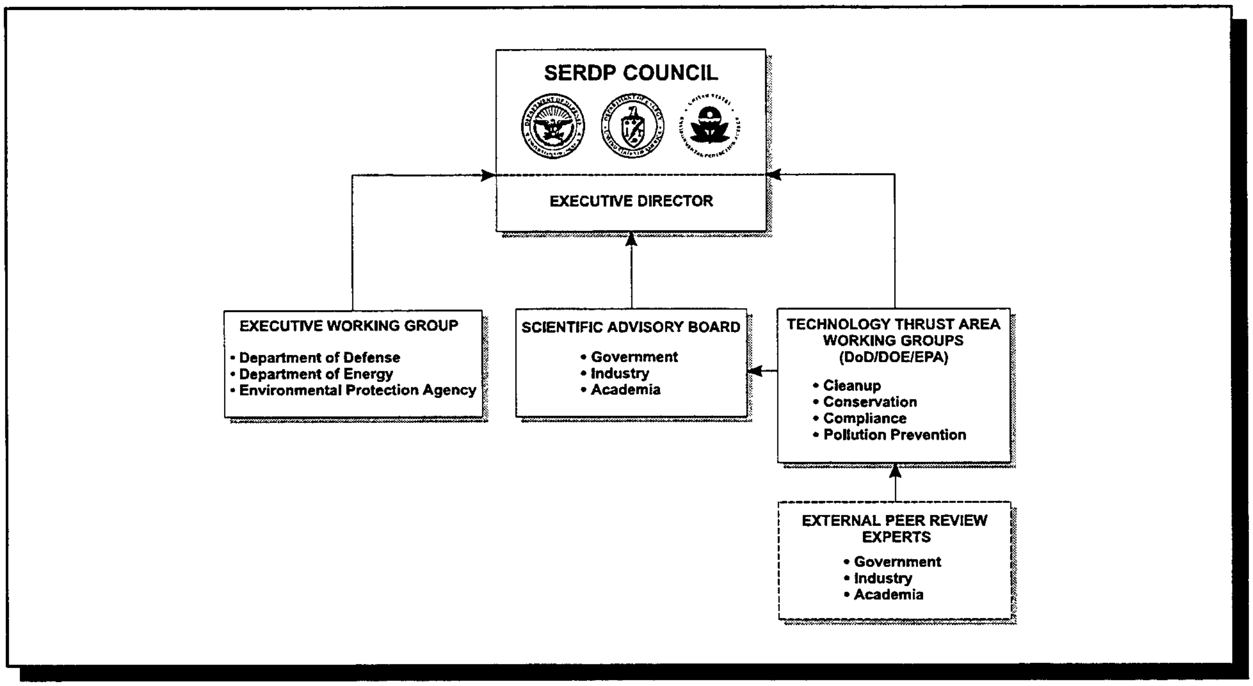

Figure 1. SERDP Organization

This report provides a summary of SERDP's activities and most significant accomplishments during fiscal year 1998, its plans for fiscal year 1999, and new initiatives to be addressed in fiscal year 2000.

SERDP Council

Established by law, SERDP's multi-agency Council ensures integrated, non-duplicative research.

Title 10, U.S.C. §2902 established the Strategic Environmental Research and Development Program Council to oversee management of SERDP. Specifically, this Council prescribes policies and procedures to implement the SERDP and may enter into contracts, grants, and other agreements in accordance with other applicable law to carry out the purposes of SERDP. Congress intended the Council to be a multi-agency membership body to promote maximum exchange of information and to minimize duplication of environmental related research, development, and demonstration activities through close coordination with the military departments and Defense agencies; the Department of Energy; the

Environmental Protection Agency; the National Oceanic and Atmospheric Administration; the National Aeronautics and Space Administration; other departments and agencies of the Federal, State, and local governments; and other organizations engaged in environmental related research.

DoD and DOE alternate as co-chairs.

Consistent with the SERDP statute and with facilitating multi-agency cooperation, the Secretary of Defense designates a member of the Council as chairperson for each odd-numbered fiscal year and the Secretary of Energy designates a member of the Council to serve as chair for each even-numbered year. Membership during the fiscal year does not remain constant. Following are the SERDP Council members who served during a portion of or for the entire FY 1998. A list of current SERDP Council members may be found on the SERDP website (www.serdp.gov/general/about/organization.html).

Council Members - FY 1998

Mr. Alvin Alm
Department of Energy
Environmental Management

Dr. Richard Chait
Department of the Army
Research Development and Acquisition

Dr. Lance Davis
Department of Defense
Defense Research and Engineering

Colonel Rick Drawbaugh
Department of the Air Force
Environment, Safety, and Occupational Health Technologies

Dr. Delores Etter
Department of Defense
Science and Technology

Ms. Sherri Goodman
Department of Defense
Environmental Security

Captain Michael Grimes
U.S. Coast Guard
Research and Development

Dr. Martha Krebs (Chair)
Department of Energy
Energy Research

Mr. Henry Longest, II
Environmental Protection Agency
Research and Development

Mr. James Owendoff
Department of Energy
Environmental Management

Dr. John Parmentola
Department of the Army
Research and Laboratory Management

General Joseph Ralston
Department of Defense
Joint Chiefs of Staff

Dr. Victor Reis
Department of Energy
Defense Programs

Dr. Fred Saalfeld
Department of the Navy
Naval Research

Mr. George Singley, III
Department of Defense
Defense Research and Engineering

Captain Gary Steinfort
U.S. Coast Guard
Research and Development

Mr. Bradley Smith *(non-voting member)*
Strategic Environmental Research and Development Program

SERDP Scientific Advisory Board

The SERDP Scientific Advisory Board (SAB), established in accordance with the SERDP statute, assures the Council's primary focus on technical quality. The SAB may make recommendations to the Council regarding technologies, research, projects, programs, activities, and, if appropriate, funding within the scope of the SERDP.

The SAB is composed of no more than 14 members who are jointly appointed by the Secretary of Defense and the Secretary of Energy in consultation with the Administrator of the Environmental Protection Agency. During the year, 14 members served on the Board, although, due to the resignation of three members, the year ended with 11 members. To ensure a program that is congruent with the Administration's goals, there are two statutory members of the SAB. They are the Science Advisor to the President, or his/her designee, and the Administrator of the National Oceanic and Atmospheric Administration, or his/her designee. Similarly, to ensure that regional and global environmental issues are appropriately addressed in SERDP, at least one member should represent the interests of State governments and one member should represent environmental public interest groups.

SAB members ensure the Council's focus on technical quality.

The *Annual Report to Congress - Fiscal Year 1998* by the SERDP SAB reviews the specific actions taken and recommendations made by the SAB during fiscal year 1998. The report was provided to Congress in March 1999.

Scientific Advisory Board Members - FY 1998

Dr. Patrick R. Atkins
Aluminum Company of America

Dr. Rosina M. Bierbaum
Office of the Science Advisor to the President

Mr. Richard A. Carpenter
Environmental Consultant

Mr. Richard A. Conway
Environmental Consultant

Mr. Amos S. Eno
National Fish & Wildlife Foundation

Dr. Raymond C. Loehr
University of Texas at Austin

Dr. Perry L. McCarty
Stanford University

Dr. Roger O. McClellan
Chemical Industry Institute of Toxicology

Dr. Michael J. Ryan (Chair)
Bechtel Jacobs Company LLC

Dr. Jean'ne M. Shreeve (Vice Chair)
University of Idaho

Dr. Lydia W. Thomas
Mitretek Systems, Inc.

Dr. C. Herb Ward
Rice University

Mr. Robert S. Winokur
National Oceanic and Atmospheric Administration

Mr. Randolph Wood
Nebraska Department of Environmental Quality

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I. EXECUTIVE SUMMARY

Introduction

This report fulfills the requirement that the SERDP Council provide an annual Report to Congress that summarizes SERDP's activities and most significant accomplishments during FY 1998, plans for FY 1999, and new research initiatives that will be addressed in FY 2000. This section, Section I, is the Executive Summary of the SERDP Program, including an overview of the SERDP mission and goals, an explanation of how the SERDP Program is managed, and highlights of SERDP activities in FY 1998. Section II summarizes significant accomplishments in each of the four thrust areas. Section III provides a description of each thrust area, including driving requirements, a list of completed, ongoing, and new start projects; and a brief summary of FY 2000 research initiatives. Detailed project descriptions for each of the SERDP thrust areas are provided in Appendices A through D. Appendix E contains Statements of Need for research proposals that will be funded in FY 2000.

This report provides a SERDP overview, Significant Accomplishments, and description of each Thrust Area Program.

SERDP Overview

Mission

Congress established SERDP in Public Law 101-510 (Title 10, U.S.C., §§2901-2904) as a Department of Defense (DoD) program planned and executed in partnership with the Department of Energy (DOE) and the Environmental Protection Agency (EPA). As such, the mission of SERDP can be found in this authorizing congressional language. Specifically, the four purposes of SERDP are to:

- Address environmental matters of concern to the DoD and the DOE through support for basic and applied research and development of technologies that can enhance the capabilities of the Departments to meet their environmental obligations;
- Identify research, technologies, and other information developed by the DoD and the DOE for national defense purposes that would be useful to governmental and private organizations involved in the development of energy technologies and of technologies to address environmental restoration, waste minimization, hazardous waste substitution, and other environmental concerns and to share such research, technologies, and other information with such governmental and private organizations;

SERDP was proposed by former Senator Sam Nunn in a Senate floor speech in November 1990.

- Furnish other governmental organizations and private organizations with data, enhanced data collection capabilities, and enhanced analytical capabilities for use by such organizations in the conduct of environmental research; and

- Identify technologies developed by the private sector that are useful for DoD and DOE defense activities concerning environmental restoration, hazardous and solid waste minimization and prevention, and hazardous material substitution and provide for the use of such technologies in the conduct of such activities.

SERDP is a "requirements-driven" program that directly responds to defense requirements generated by the Services and sanctioned by the Deputy Under Secretary of Defense for Environmental Security (DUSD/ES). DoD environmental concerns may be divided into two broad categories of concerns both of which can negatively impact the Department's ability to perform its primary mission of maintaining military readiness for national defense—those concerns that impact training, logistics, and combat operations, and those concerns that have cost and performance impacts on the supporting infrastructure.

SERDP continues to improve mission readiness through environmental research by:

✔ Accelerating cost-effective cleanup of contaminated defense sites;

✔ Facilitating full compliance with environmental laws and regulations at reduced cost;

✔ Enhancing training, testing, and operational readiness through prudent land management and conservation measures; and

✔ Reducing or eliminating defense industrial waste streams through aggressive pollution prevention.

In FY 1998, SERDP remained dedicated to solving DoD environmental problems by providing a forum for environmental technology partnership. As the DoD's corporate environmental Science and Technology (S&T) program, it fully leverages complementary programs found within the Army, Navy, and Air Force, as well as those of the DOE and the EPA. In past actions, the SERDP Council implemented policies to take full advantage of the intrinsic capabilities of the participating organizations and has guided the development and execution of the Program consistent with the SERDP authorizing statute. These participating organizations make SERDP unique; SERDP truly can tap the vast technical resources of the Federal laboratory infrastructure to meet the needs of our most difficult environmental matters of concern.

SERDP Program Goals

SERDP's goals, as prescribed by the SERDP Council:

- Resolve environmental concerns in ways that enhance military operations, improve military systems' effectiveness, and help ensure the safety of personnel; and
- Support technology and process development that reduce operational and life-cycle costs, including those associated with environmental cleanup and costs of full compliance with environmental laws and regulations.

In the course of addressing DoD's highest priority environmental needs in the areas of Cleanup, Compliance, Conservation, and Pollution Prevention, SERDP also has sought opportunities to help solve

other significant national and international environmental problems through the application of DoD's technical capabilities, analytical systems, and information.

SERDP has achieved its goals through the following methods:

- Identifying and supporting programs of basic and applied research and development to:
  - facilitate environmental compliance, remediation, and conservation activities;
  - minimize waste generation, including reduction at the source; and
  - substitute use of non-hazardous, non-toxic, non-polluting, and other environmentally sound materials, substances, and processes;
- Promoting the effective exchange of information regarding environmentally related research and development activities;
- Ensuring that SERDP research and development (R&D) activities complement, but do not duplicate, Tri-Service R&D programs and other ongoing activities;

SERDP is a Requirements-Driven Program.

- Providing appropriate access to data under the control of, or otherwise available to, the Departments of Defense and Energy that is relevant to environmental matters;
- Facilitating the transfer of unclassified DoD and DOE environmental information and technology to other sectors of society which might be able to use them to advance national environmental objectives; and
- Emphasizing multi-service, inter-departmental research and development projects and using the unique capabilities of the partnering Federal agencies, private industry, and academia to solve the Departments' environmental problems.

Research Framework

The Deputy Under Secretary of Defense for Environmental Security sets most Program requirements.

Figure I-1 represents the research taxonomy that was used in FY 1998 to define the SERDP Program. As the DoD's corporate environmental R&D program, SERDP developed its primary Thrust Areas in response to user community needs for science and technology required to accomplish the military mission in an environmentally compliant manner. Accordingly, these Thrust Areas - Cleanup, Compliance, Conservation and Pollution Prevention - are consistent with the focus of the Office of the Deputy Under Secretary of Defense for Environmental Security (ODUSD(ES)), and they directly parallel the four pillars of the Tri-Service Environmental Quality Technology programs. The SERDP Thrust Areas also correspond to those identified in the National Environmental Technology Strategy.

CLEANUP	COMPLIANCE	CONSERVATION	POLLUTION PREVENTION
Unexploded Ordnance Detection	Air	Maintain/Enhance Training Capability	Air
Site Characterization and Monitoring	Water	Natural Resource Stewardship	Water
Remediation	Solid	Cultural Resource Stewardship	Solid
Risk Assessment Technologies	Noise*		Modeling and Databases

* The Compliance Noise Subthrust was moved to Conservation in FY98.

Figure I-1. Research Taxonomy

SERDP leverages and interacts with other environmental programs to identify and solve defense specific needs, extend applications of defense information to others, and build on existing science and technology to derive more useable and cost-effective approaches for achieving reductions in environmental risks. The efforts collectively facilitate acceptance by Defense Systems Program Executive Officers (PEOs) and transition to the commercial sector. Figure I-2 illustrates SERDP's role in the environmental technology development process.

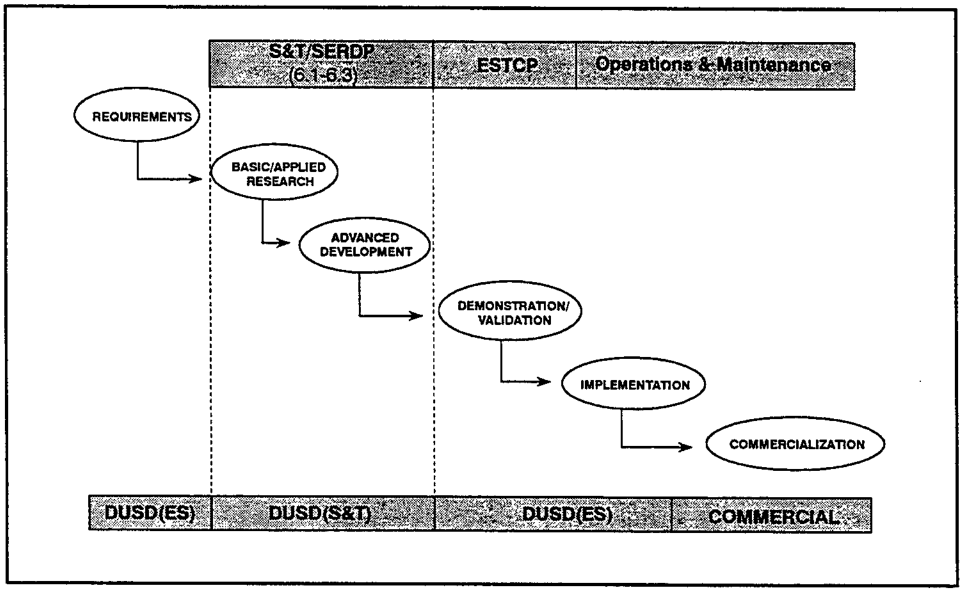

Figure I-2. Environmental Technology Development Process

In the past, SERDP projects have depended on the Services' Environmental Quality Technology programs, weapons systems engineering development programs, and the Environmental Security Technology Certification Program (ESTCP) to capture S&T research and transition these products to the field. The co-location of the ESTCP and SERDP Program Offices is a major step forward toward ensuring a close cooperation between research and development projects and the actual demonstration of environmental technology to the users in the field.

Program Management and Oversight

SERDP Council

Actions

Multi-agency management and oversight of the Program continues to be one of the clear strengths of SERDP. Active participation by the members of the SERDP Council, and their designated representatives on the Executive Working Group (EWG) and Technology Thrust Area Working Groups (TTAWG), facilitates information transfer and ensures quality Program content. Composed of programmatic and technical individuals that represent the three primary participating organizations, tri-parte arrangement brings with it a breadth of knowledge and experience at several levels of management and technical expertise lending significant credibility to the Program.

On September 26, 1997, the SERDP Council approved the FY 1998 Program Plan and codified the FY 1999 Strategic Guidance and Investment Plan. In FY 1998, the SERDP appropriation increased from $54.9 million to $61.9 million. Seven million dollars was added to the President's Budget Request to fund three Congressional interest projects. In effect, the amount of discretionary funding for SERDP had not changed significantly.

Multi-Agency management is a clear strength of the Program.

The Council was pleased with SERDP's first attempt to reach out to a broader pool of researchers through a Broad Agency Announcement. Council members expressed their desire to continue this practice to include the non-Federal sector in addition to the Federal partners. Seeking to make this offer attractive to the non-Federal participants and ensure their effective participation, the Council set 20 percent as a proposal selection rate goal for FY 1999.

One year later on September 29, 1998, the SERDP Council met again to approve the FY 1999 Program and the FY 2000 Investment Plan. The Council reviewed the results of the FY 1999 solicitation process including a summary of projects awarded to both Federal and private organizations. The solicitation resulted in 173 preproposals from non-Federal sources and 143 full proposals from both Federal and non-Federal sources in response to the 15 Statements of Need. Overall, the Federal sector submitted 62 percent of the proposals, 20 percent were received from industry, and 18 percent were forwarded from academia. SERDP provided $10.0 million for the New Start efforts, and approximately $4.4 million of this amount was competitively awarded to the non-government performers. The Council's 20 percent selection rate goal for non-Federal participants had been reached.

A separate solicitation was conducted later in FY 1998 for a new initiative called the SERDP Ecosystem Management Project (SEMP). It resulted in an additional three projects, two of which were submitted by the Federal sector. Figure I-3 depicts the distribution of proposals selected during the FY 1999 program development process.

Thrust Area	No. of Statements of Need	No. of Proposals Selected	SOURCE			Approximate Value (Thrust Total)
			Federal	Academia	Private	
Cleanup	4	9	5	3	1	$3.3 million
Compliance	3	3	2	0	1	$1.1 million
Conservation	3	4	2	0	2	$1.6 million
Pollution Prevention	6	9	4	2	3	$4.0 million
Total	16	25	13	5	7	$10.0 million

Figure I-3. FY 1999 New Start Proposal Distribution By Thrust Area

Technical Strategy

For FY 1998, the SERDP Council directed the continuing pursuit of six avenues in planning and executing defense mission-relevant environmental research and development:

- ✔ Identify and fund major-impact, multi-agency environmental R&D programs to solve high-priority, mission readiness related concerns of DoD;
- ✔ Identify opportunities to accelerate existing DoD environmental quality R&D programs and fund those that address the highest priority concerns of the Department;
- ✔ Identify, leverage, adapt, and/or adopt existing technologies to address environmental concerns of DoD and DOE;
- ✔ Advance and use applicable state-of-the-art modeling and simulation capabilities to accomplish SERDP goals;
- ✔ Use the technical and research capabilities of the SERDP partners, including their unique data collection and analysis capabilities, as appropriate; and
- ✔ Plan for a transition of successfully proven technologies to demonstration and validation or to commercialization and implementation.

Investment Strategy

The SERDP Council annually determines the distribution of funding to the Thrust Areas. Figure I-4 depicts the percentage of Program funding trends for each technology Thrust Area from FY 1998 through FY 2003.

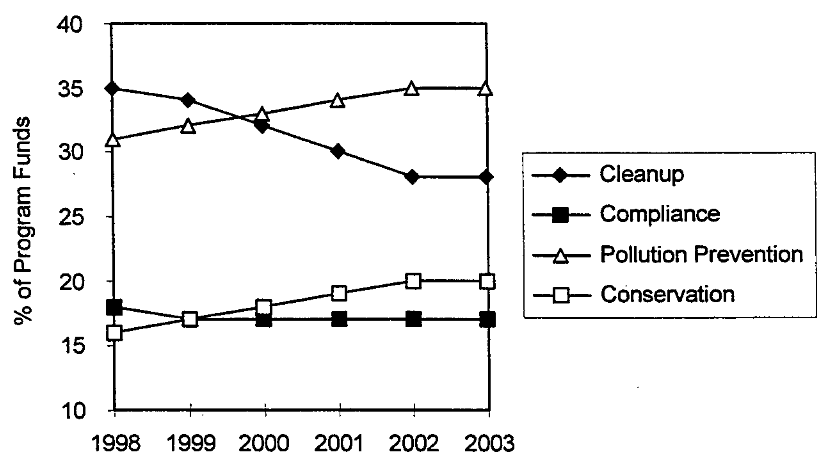

Figure I-4. Funding Balance Across the SERDP Thrust Areas

Forecasts are based on known or expected requirements and stated goals of the Services and ODUSD(ES). Requirements for R&D may change from year to year; consequently, these trends may not reflect actual investments.

DoD has set specific Cleanup goals for completion in the future. Accordingly, in order to impact these goals, technologies currently under development must be delivered to the field in the near future. Hence, the investment in Cleanup is expected to decrease over the next five years. This is part of the conscientious shift within the DoD from a cleanup posture to one of preventing pollution. However, investments in UXO detection technologies will continue to be a significant part of the Cleanup Thrust Area in the next years.

DoD seeks to take a prevention-based posture.

A focused investment to eliminate future waste streams will reduce sharply or preclude the environmental consequences experienced in the past. Clearly the biggest returns in the future are expected by reducing or eliminating generation of pollutants. Accordingly, an increase in Pollution Prevention technology investment is anticipated over the next five years.

Current environmental regulations often preclude, or severely restrict, military training, operations, and manufacturing activities, if they are not in total compliance. The current regulatory environment has been relatively stable in recent years. A commensurate slight decrease of effort in SERDP's Compliance investment is anticipated based on the shift from end-of-pipe treatment to pollution prevention; however, this could change with a reinvigorated environmental regulatory agenda.

Conservation technologies have the potential to have the greatest impact on the readiness of military units. Research results from this area will help to resolve legal stalemates and promote environmentally sound land use management. Substantial efforts have been initiated in Conservation, such as the SERDP Ecosystems Management Program. Accordingly, investments in Conservation efforts are anticipated to increase as research efforts mature to demonstration.

Scientific Advisory Board

The SAB wants to ensure that SERDP retains a "strategic" focus.

The SERDP Scientific Advisory Board (SAB), in their reaffirmation that SERDP be proactive and visionary as opposed to reactive, discussed how best to keep SERDP 'strategic' in scope. They concluded that each and every project was reviewed during this fiscal year in the context of the defined characteristics that are associated with a 'strategic' defense R&D program. In framing this context, SERDP should concentrate on research that is (1) essential for the solution of major defense mission-readiness related problems; (2) scientifically plausible; (3) focused on areas where progress under other program sponsorship in DoD and/or other agencies is not sufficient or satisfactory; (4) catalytic in nature to initiate, organize, and accelerate essential research in partnership with the Federal and private sector; and (5) certain to provide sufficient proof of principle demonstrations to attract follow-on Research Development Test & Engineering (RDT&E) support.

Further, the SAB reviewed each project to ensure that the ultimate recipient military Service contributed direct or in-kind resources as the project progressed and that this use became increasingly involved in planning for project transition into the field. At the September 1998 Council meeting, candid remarks were provided by Dr. Michael Ryan, Chair of the Scientific Advisory Board. His historic perspective of the Program's development and maturation added a confidence factor for the Council members that the Program is continuing to take the correct measures and is proceeding appropriately.

Executive Director and Program Office

Key Metrics for SERDP Success

The SERDP Executive Director, with the Council's direction, carried out the FY 1998 program and FY 1999 program development activities. The following four key metrics were used to maintain Program quality and enhance the success of the Program in FY 1998.

Address the Highest-Priority, Defense Mission-relevant Environmental Requirements with Emphasis on Multi-Service Issues.

The Executive Director and his Program Managers worked hand-in-hand with ODUSD(ES) to establish clear lines of communication, address effectively the Department's highest priority environmental requirements, and foster transition of technical efforts to field demonstration or implementation. Acting on the advice of the SERDP Council and the Scientific Advisory Board to embrace the widest competition in the selection of the proposals for FY 1998, the Executive Director opened the SERDP solicitation process to the non-Federal sector. Through the use of tailored Statements of Need, the Executive Director solicited cooperatively funded and executed projects to address high-priority multi-service needs. The TTAWGs, SERDP's multi-agency planning and coordinating bodies, facilitated this process by communicating effectively and applying their knowledge of the needs and capabilities of the Federal R&D infrastructure.

In June of 1998, SERDP held a workshop on exploring the state-of-science, technology gaps, and opportunities for research in the area of Environmentally Acceptable Endpoints for metals, solvents, and energetic materials in soils. SERDP worked with the American Academy of Environmental Engineers to address this timely and controversial issue; one that, if resolved, could save cleanup costs by many millions of dollars and shorten cleanup time by years, if not decades. From this workshop, several key Statements of Need were identified. Based upon the successful results of this workshop, another workshop will be held in FY 1999 on the subject of Air Emissions, emphasizing military diesels, turbines and ordnance training operations.

Pursue/Achieve Universal, World-Class Technical Excellence.

World-class research is considered the cornerstone of SERDP projects. SERDP continued the use of an external peer review process in addition to the existing comprehensive multi-agency review procedures ensuring that technically sound proposals performed by world-class researchers are selected for funding. Technical experts representing universities, industry,

and government participate in the Peer Review process. Additionally, the SAB, TTAWGs and the Program Office staff all emphasize and ensure that each research team demonstrates superior technical merit and performs according to world-class research standards.

Transfer of technology, from research to the DoD environmental user community, is a key objective of SERDP. This overall program objective is achieved by supporting applied research and technology demonstrations that respond directly to high-priority DoD mission related environmental needs. With FY 1998 marking its seventh year of technology development, SERDP is aggressively pursuing technology transfer mechanisms. Many of the projects initiated in the earlier years have been or are being completed and are now ready for implementation or transition to the next step of development.

Emphasize Technology Transfer.

The SERDP Executive Director, Technical Director, and the Program Managers aggressively emphasized transfer of SERDP sponsored research results to the Defense users and/or the next steps of development, demonstration, or commercialization. Co-location of the SERDP Program Office and the Environmental Security Technology Certification Program (ESTCP) Office provides DoD with a well-coordinated corporate 6.1 (Basic Research) through 6.4 (Demonstration/Validation) environmental research and development management structure. This relationship already has yielded high dividends by fostering excellent coordination and successful transition of research and development projects to the users.

Additionally, increased focus on technology transfer has been placed on the Principal Investigators (PI) of all SERDP projects at both briefings to the SAB as well as at the In-Progress Reviews. At these IPRs, PIs are required to demonstrate their interaction with the user community or those who will sponsor further development. Members of the multi-agency TTAWGs, Joint Engineers Management Panel (JEMP) members, and key representatives from ODUSD(ES) were in attendance and provided various potential technology transfer opportunities to the PIs. In December 1998, the annual Partners in Environmental Technology Technical Symposium and Workshop sponsored by SERDP once again succeeded in providing an excellent technology transfer and networking forum for researchers, scientists, and engineers from both the Federal laboratory system and the non-Federal sector alike, which achieved it's largest attendance to date. This venue, which achieved its largest attendance to date, will continue to be enhanced and expanded and will serve as a significant annual technology transfer event.

A salient example of SERDP technology transfer in FY 1998 was the application of a SERDP funded technology, the Mobile Undersea Surveillance System (MUDSS), to assist in the mission following the tragic Swissair Flight 111 disaster. MUDSS works by combining sonar and other technologies into a single submersible, torpedo-like vehicle for detecting unexploded ordnance in shallow water. MUDSS allowed the search team to define the debris field off the coast of Nova Scotia quickly and accurately.

Ensure Sound Fiscal Management.

Timely and complete financial reporting is one of the principal keys to SERDP's success. The SERDP Executive Director has continued to ensure that the Program complies with the DoD fiscal guidance. Effective controls include periodic fiscal review of projects, implementing aggressive corrective actions to promote effective

use of scarce R&D resources, and implementation of various information management/monitoring tools system.

Plans for FY 1999

Plans for the SERDP Program in FY 1999 include the following:

- Consolidation of the SERDP and ESTCP Program Offices has caused increased demands on the Program Managers for each of the four Thrust Areas. Responsibilities have increased with added emphasis on technology demonstration and transition initiatives. An additional Program Manager will be added to handle SERDP and ESTCP Pollution Prevention activities.

- Continue non-Federal sector direct participation via Broad Agency Announcements for the solicitation of FY 2000 proposals. Likewise SERDP will continue external peer review for evaluating FY 2000 proposals received from both the Federal and non-Federal sectors.

In FY99, SERDP will continue to seek world-class research in support of DoD needs.

- Continue to bridge technology from Science and Technology through to Dem/Val by conducting annual In-Progress Reviews in conjunction with ESTCP.

- At the recommendation of the SERDP Scientific Advisory Board, conduct a Compliance Workshop in early summer 1999 to address research needs for air emissions of military diesels, turbines, and ordnance training operations.

- Conduct the annual Technical Symposium and Workshop, focusing on technology transfer and increasing awareness of SERDP and SERDP-related efforts within the DoD user community.

For FY 1999, SERDP plans to continue providing world-class research in response to the Department's highest priority environmental needs in serving in its role as the DoD Corporate Environmental R&D program.

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II. SIGNIFICANT ACCOMPLISHMENTS

Introduction

SERDP continues to play a pivotal role in the development of science and technology that supports the Department of Defense's environmental security goals. Responding to DoD's highest priority requirements, SERDP has supported more than 257 environmental science and technology projects since its inception in 1991. These projects have enabled DoD installations to meet their environmental responsibilities in cost-effective and innovative ways. A number of SERDP's most significant accomplishments during the past year are described below. While these projects represent just a small selection of the many innovative and ground-breaking projects supported by SERDP, they illustrate the breadth and depth of the Program and highlight the most significant accomplishments of FY 1998. Furthermore, these accomplishments demonstrate the potential enormous cost savings that will be realized while simultaneously maintaining mission readiness, when new technologies become fully implemented. Appendices A through D provide detailed information on each SERDP project.

Cleanup Accomplishments

UXO

Unexploded ordnance (UXO) has emerged as one of DoD's most pressing environmental cleanup problems. UXO presents a challenge to active military installations seeking to manage and clean their test and training ranges, to sites designated for base realignment and closure (BRAC), and to formerly used defense sites (FUDS). In the United States alone, current estimates indicate that more than 900 sites (11 million acres) with varying terrain, foliation, and topography (including 50 underwater sites) are potentially contaminated with UXO. Using current technologies, the cost of identifying and disposing of UXO in the U.S. is estimated to range up to $500 billion. New technologies capable of detecting UXO with high detection rates and low false alarm rates are required to drastically reduce the cost of site cleanup. SERDP is investing in UXO technology development through nine projects, including three FY99 New Starts and one project completed in FY98. Figure II-1 depicts typical UXO that researchers encounter in the field.

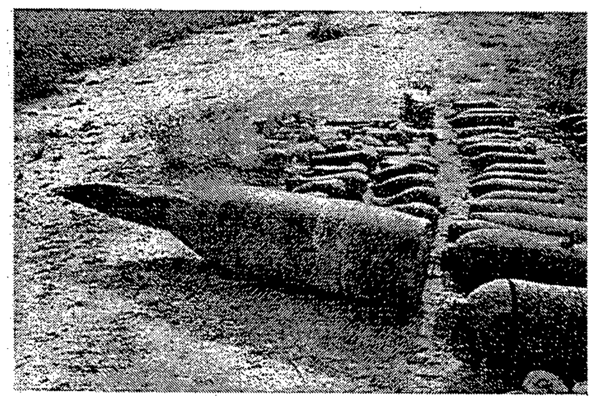

Figure II-1. Typical UXO to Be Detected by SERDP Technologies

Effort was increased in FY98 to improve coordination and cooperation between SERDP-funded UXO related efforts. To facilitate this coordination, a SERDP-funded UXO exchange meeting was held in May 1998. Based on the success of that meeting, SERDP will sponsor another UXO Technology Exchange Meeting in FY99 that will include both SERDP- and ESTCP-funded UXO efforts. Benefits of the

increased level of communication can be seen in a FY99 New Start effort in which investigators performing data fusion and interpretation will utilize numerous existing data sets generated under SERDP-funded UXO projects.

The SERDP-funded **Mobile Underwater Debris Survey System (MUDSS) Program (CU-52)** is designed to locate and identify underwater unexploded ordnance (UXO). Researchers planned to complete integration of sensors and perform field tests in this final year of SERDP funding. The unfortunate Swissair Flight 111 mishap offered researchers the opportunity to determine the capabilities of MUDSS in a real-world operational setting.

In the Swissair application, MUDSS successfully allowed the Canadian Armed Forces and the Canadian Coast Guard search teams to quickly and accurately define the debris field off the coast of Nova Scotia. System performance information, provided in Figure II-2, shows how an advanced system, such as MUDSS, can outperform human divers which were used extensively in "Operation Persistence" in Peggy's Cove. John McCormick, a MUDSS project engineer at the Navy Coastal Systems Station, Panama City, Florida, said MUDSS had never been used operationally. He called the Swissair 111 search operation "...a real success... [and] the acid test of what is an experimental system".

MUDSS Performance Off Peggy's Cove, Nova Scotia

- **Operated Electro-Optical (EO) sensor in water depths of 180'**
- **Operated Synthetic Aperture Sonar (SAS) in water depths of 110'**
- **At sea for 4½ days - about 900 nmi**
- **SAS surveyed about ½ nmi^2**
- **EO surveyed about 1½ nmi^2 - about a 200 mile track**
- **EO surveyed about 1½ nmi^2 - about 40 hours at operating depth 30$\pm$5ft from bottom with high quality imagery**

Figure II-2. MUDSS Performance

Depicted in Figure II-3, MUDSS works by combining sonar and Electro-Optical Identification Sensor (EIS) technologies in a single submersible, torpedo-like vehicle that feeds high-speed data to a mothership via a fiber-optic cable. This package enables the Navy to use the sonar to locate objects on the ocean floor and then to use the EIS to zoom in and identify those objects at closer ranges. In FY98, hardware and software modifications were made to the original MUDSS data collection system to support system design changes. MUDSS is a joint U.S. Navy and NASA effort executed by the Naval Surface Warfare Center (NSWC) and the Jet Propulsion Laboratory (JPL).

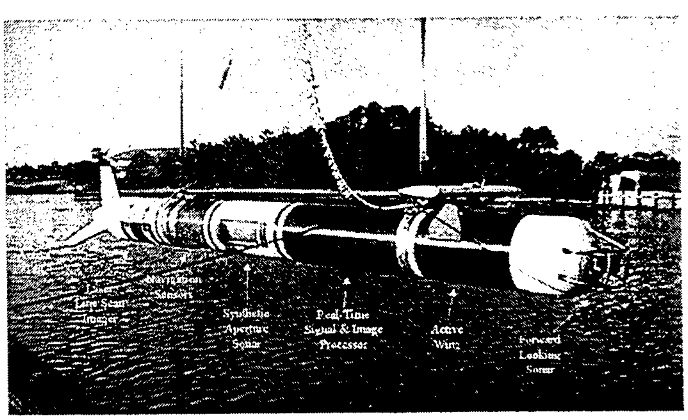

Figure II-3. MUDSS Sensor as Deployed for the Swissair Investigation

SERDP continued funding two radar-based efforts initiated in FY97 to assess the ability of non-traditional sensors to detect and discriminate UXO from background clutter.

The effort, **Low-Frequency, Ultra-Wideband Boom Synthetic Aperture Radar (Boom-SAR) for Remote Detection of Unexploded Ordnance (CU-1070)**, is exploring the use of low-frequency, ultra-wideband (50 MHZ - 1200 MHZ) SAR. SERDP is leveraging extensive DoD investment in this area by exploiting the Boom-SAR. The Boom-SAR, from heights of up to 150 feet atop a mobile boom platform, is a side-looking ground-penetrating radar which can cost effectively mimic airborne platforms (Figure II-4). Significant progress was made in FY98. Two separate Boom-SAR data collection efforts were conducted at the ground-truthed Yuma Proving Ground UXO test area. Processing and analysis of this data will take place in FY99. Also in FY98, an extensive UXO test site, possessing unique soil and groundwater characteristics, was established at Eglin Air Force Base (AFB), Florida. The Air Force Research Laboratory (through a collaboration with the Army Research Laboratory [ARL]) characterized subsurface anomalies at the Eglin AFB test area using their electromagnetic induction sensors. This was done at no cost to the SERDP effort. Boom-SAR data will be collected at the Eglin AFB site, processed and analyzed during FY99. This effort is being conducted by the ARL.

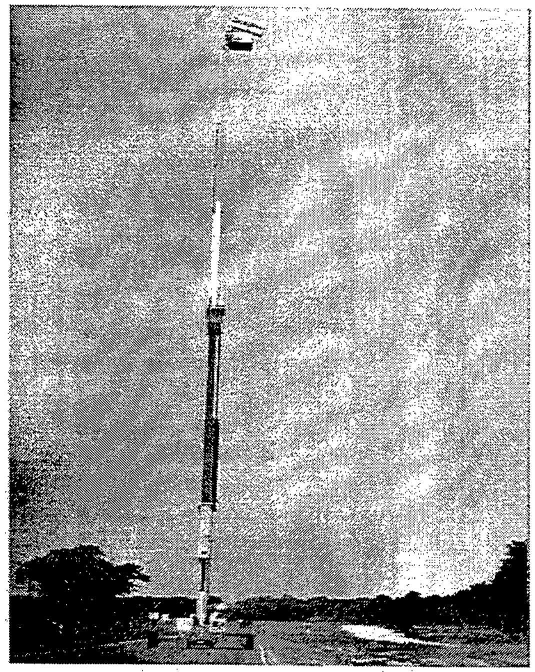

Figure II-4. Boom-SAR Deployed for UXO Detection

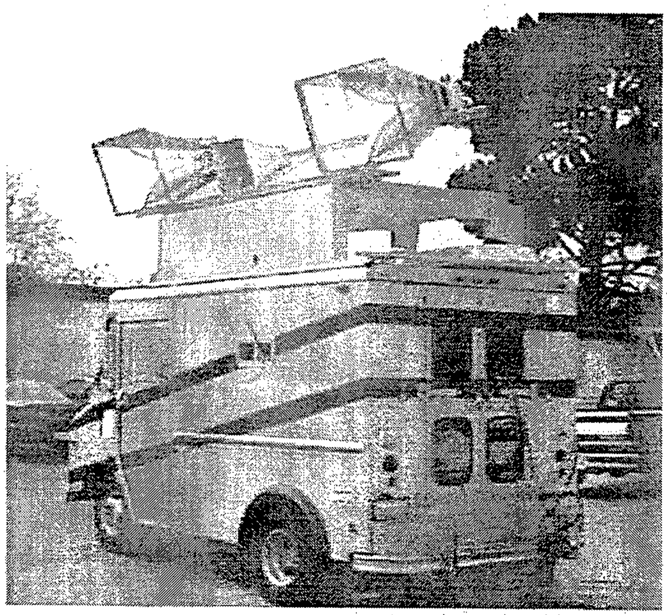

Figure II-5. Van-Mounted Harmonic Radar for UXO Detection

In a complementary radar-related effort, **UXO Detection by Enhanced Harmonic Radar (CU-1071)**, a third harmonic SAR is being used to detect and discriminate shallow UXO objects. In FY97, this project successfully responded to a Scientific Advisory Board (SAB) directive to perform an initial proof-of-concept demonstration prior to pursuing the balance of the project's proposed objectives. Following this successful proof-of-concept, the project continued to make advances in FY98. Researchers made significant progress to improve the ultra wideband (UWB) third harmonic measurement capabilities. In addition, the impulse high-voltage system has been calibrated with good overall repeatability. Significant progress also was made in developing the van-mounted measurement platform; the radar was assembled, upgraded, and tested. Installation of a variable elevation

angle antenna system has been completed and tested. This system consists of a high voltage transmit horn with a built-in third harmonic suppression filter and two receive horns; one for the fundamental band and one for the third harmonic band. This van-mounted system is depicted in Figure II-5.

Bioremediation

The remediation of DoD sites using existing technologies is problematic from an economic, technical, and political point of view. The projected costs associated with site restoration are estimated to be on the order of $30 billion dollars. Currently used technologies are frequently invasive, requiring the movement of large volumes of soil and/or water, and are also energy and materials intensive. In addition, many of these technologies simply transfer the contaminant from one media to another, where it often still requires treatment. The **Federal Integrated Biotreatment Research Consortium: Flask to Field Initiative (CU-720)**, is a large, multifaceted project to develop field-ready biotechnologies in each one of the following focus areas: 1) Explosives; 2) Chlorinated Solvents; and, 3) Polychlorinated Biphenyls (PCB). The target is to develop inexpensive, field-ready, biotreatment processes. Key accomplishments in FY98 under this umbrella project are detailed below.

Bioremediation of Explosives

Explosives contamination represents one of the most prevalent types of organic contamination within the DoD. Therefore, a variety of innovative and promising biotreatment techniques with potential high payoff have been investigated for remediating soil and groundwater. FY98 saw the successful field operation of a fluidized bed reactor (FBR) used to treat groundwater contaminated with dinitrotoluene at the Volunteer Army Ammunition Plant (VAAP) in Tennessee. The field-scale FBR is shown in Figure II-6.

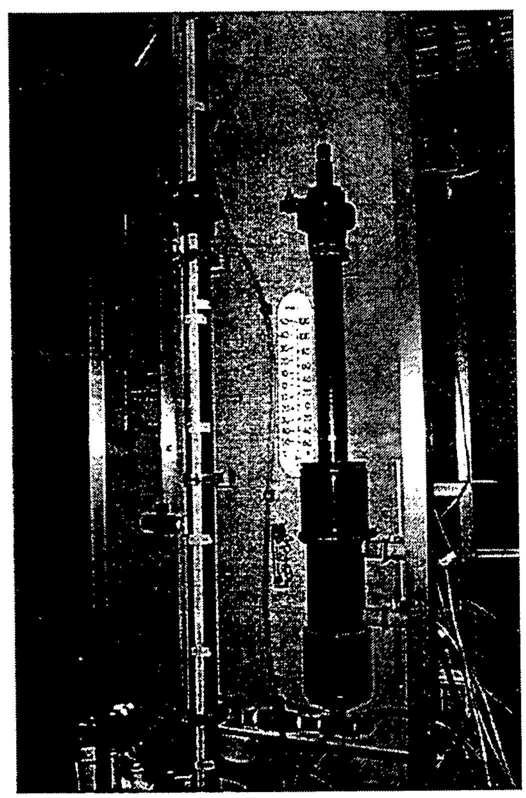

Figure II-6. The Pilot-Scale Fluidized Bed Reactor at VAAP

Bacteria capable of destroying dinitrotoluene were isolated in previous studies by researchers at the Air Force Research Laboratory, Tyndall AFB, Florida. The bacteria are immobilized on solid carriers (sand and granular activated carbon) which reside inside the FBR. Bench-scale studies conducted in FY98 showed complete degradation of several parts per million dinitrotoluene in water. No additional nutrients were required for successful operation of the process and the system was stable over a wide range of operating conditions. The bench-scale success was verified by conducting a pilot-scale field demonstration at VAAP. The process successfully operated under varying feed flow rates and varying dinitrotoluene concentrations. The pilot

study was completed in August 1998. The final report will be published in FY99 and will contain an economic evaluation of the FBR technology and compare these costs to those of conventional competing technologies.

Bioremediation of PCBs

The fundamental barriers to biodegradation of PCB contamination are (1) the absence of suitable bacteria in most contaminated soils, (2) the slow rate of degradation and the fact that the degradation process halts before it is complete, and (3) the low solubility and hence, poor bioavailability of PCBs. Under **CU-720** in FY98, researchers pursued the genetic engineering of organisms capable of growing on PCB contamination. Significant progress was made in developing bacteria that are stable under laboratory conditions. Work will continue in FY99 to determine the survivability of the bacteria in actual PCB contaminated soils. To overcome the problem associated with the low solubility of PCBs, work in FY98 also focused on evaluating surfactants that could potentially enhance PCB bioavailability and biodegradation. Surfactants that increase PCB solubility without inhibiting bacterial activity were successfully identified in FY98. Work will continue in FY99 to move towards a field-scale experiment involving the augmentation of PCB contaminated soils with these engineered bacteria.

Environmentally Acceptable Endpoints Initiative

SERDP Holds an Environmentally Acceptable Endpoints Workshop

Considerable research has been underway in recent years to identify Environmentally Acceptable Endpoints (EAE) in soil, to develop protocols that can be used to determine EAEs, and to make site-specific cleanup decisions based upon EAE data. EAEs for soil are most commonly defined as concentrations of chemicals or other measures of contamination (e.g., biological response or leachability) that are judged acceptable by a regulatory agency or an appropriate entity either a'priori - as in a standard or a guideline - or following an analysis of site-specific information. To date, these efforts have focused on contaminants such as petroleum hydrocarbons and on polyaromatic hydrocarbons (PAH).

SERDP recognized that the premises related to chemical availability and EAEs defined for petroleum hydrocarbons and PAHs may be applicable to DoD contaminants of concern such as chlorinated solvents, organic compounds associated with explosives, and metals. The SERDP Council endorsed a SAB recommendation to organize a workshop to (1) examine the state of the art and the uncertainties associated with defining endpoints in soil and sediments resulting from natural and/or remedial processes, (2) identify gaps in the current knowledge base, and (3) identify research opportunities where SERDP investment can have the largest impact.

The workshop was held in June 1998, in collaboration with the American Academy of Environmental Engineers. Sixty three engineers and scientists with recognized applicable experience participated in the workshop. The research objectives identified by the group served as the foundation for two of the FY99 SERDP Statements of Need (SON). The first projects responding to these SONs will be initiated in FY00.

The results from the workshop will also be made available to the public via a book to be published in FY99 by the American Academy of Environmental Engineers.

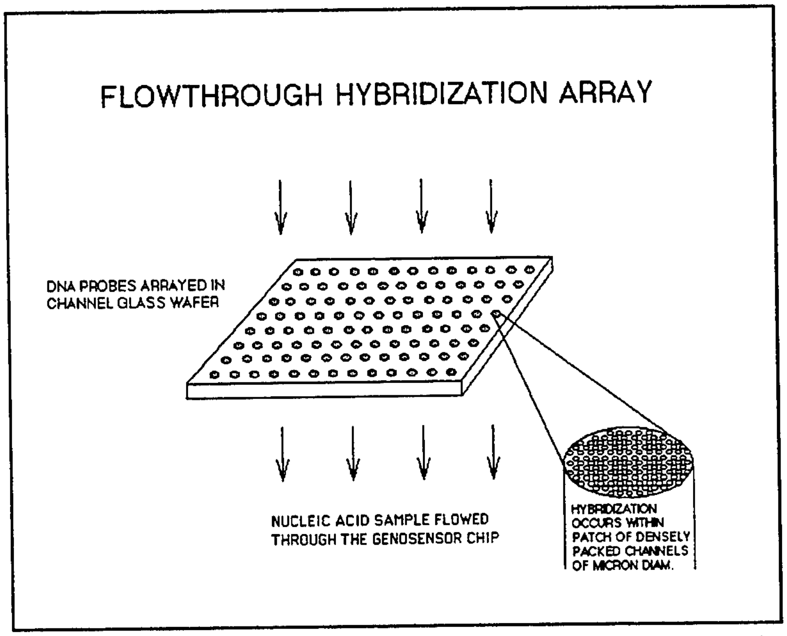

Figure II-7. Schematic Diagram of the Technical Approach of the Genosensor

A SERDP project initially funded in FY98, **Genosensor-Based Ecotoxicity Response Assessment (CU-1081)**, will also provide insight for the establishment of effective EAEs. Researchers are developing cost effective methods and instrumentation for directly monitoring genotoxic exposure in a variety of natural ecosystems. These efforts will expand capabilities for surveillance of toxicity to ecological receptors by incorporating a comprehensive collection of molecular endpoints associated with military-relevant compounds. This will greatly facilitate site characterization, risk assessment, and monitoring of the progress of remediation efforts at DoD and DOE installations. Such capabilities for rapid, multispecies biological endpoint monitoring that are ecologically relevant to cleanup of contaminated sites, should provide a rational basis for reduced cleanup costs. The new technology is expected to enable site closures in a shorter period of time, bringing significant long-term cost savings.

This technology employs novel channel glass biosensor chips (Figure II-7) containing arrays of DNA probes to characterize and monitor the response of soil microorganisms to exposure to contaminants. In FY98 probes were designed to enable detection of genotoxicity responses across bacterial species. Progress also was made in developing and refining methods for extraction of intact DNA and RNA from sediments and soils.

Chlorinated Solvents

Chlorinated solvents account for a significant portion of environmental contamination requiring cleanup action. These contaminants have migrated through the subsurface and entered the groundwater at more than 1,000 DoD sites. There is a comparable degree of contamination at DOE and private industrial Superfund sites. The technology chosen for remediation at more than 90 percent of the sites with contaminated groundwater is pump-and-treat. Estimates of the duration of pump-and-treat necessary to remediate contaminated sites range from decades to centuries, with the exposure risk continuing until remediation is achieved. Although pump-and-treat can be effective in controlling the migration of

contaminated groundwater, in-situ alternative treatment technologies are required to better remediate chlorinated solvent contamination.

A component of the DoD's National Environmental Technology Test Sites (NETTS) Program, is the **Dover National Test Site (DNTS) (CU-866)**, located on Dover AFB, Delaware. Depicted in Figure II-8, the Dover AFB National Test Site is the only test site in the United States uniquely designed and permitted for experiments involving the controlled, contained release of dense nonaqueous phase liquids (DNAPLs). Specially designed, double-walled experimental cells were constructed within the naturally occurring water table aquifer. Researchers can release known quantities of chlorinated compounds into the cells and then test various treatment technologies. A benefit to this approach is knowing the contaminant mass prior to treatment, which allows for good contaminant mass balances leading to more precise quantitative performance evaluations.

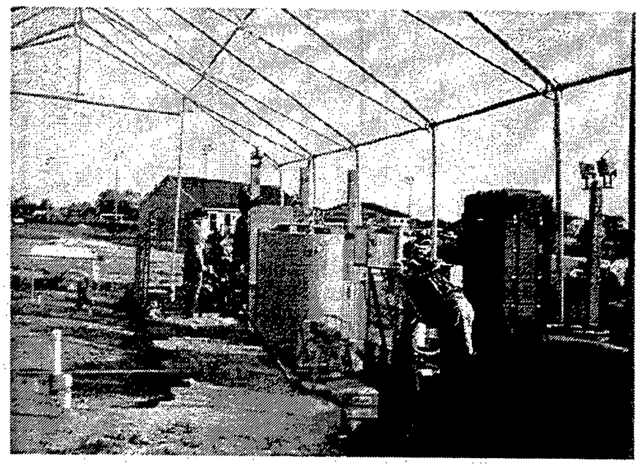

Figure II-8. The Dover Test Site Allows for DNAPL Controlled Release Experiments

Activity at Dover during 1998 included research under another SERDP-funded project, **Aquifer Restoration by Enhanced Source Removal (CU-368)**. This project is performing a series of tests to demonstrate flushing techniques for removing DNAPL. This effort is led by the EPA with collaborations with several universities and the Air Force Research Laboratory. In FY98, two double-walled test cells were installed and instrumented tetrachloroethene (PCE) was released into the one of the test cells in June 1998 and tests have been conducted to define the contaminant distribution within the test cell. Hydrodynamic characterization of the second test cell was also completed in FY98. FY99 will see the evaluation of four treatment technologies in the test cells.

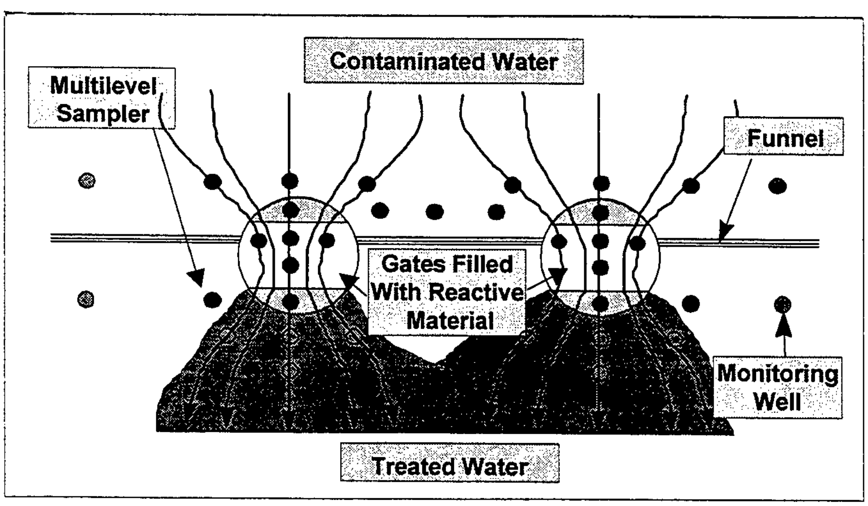

Figure II-9. Permeable Barrier Design

One of the most promising in-situ treatment technologies is in situ permeable reactive walls. This technology, also called "funnel and gate," consists of impermeable barriers installed in the ground to funnel the flow of contaminated groundwater towards a permeable section,

or gate, in the wall which contains a reactive media that will destroy the contaminants as the water passes through. **Permeable Reactive Barriers for In-Situ Treatment of Chlorinated Solvents (CU-107)**, has installed an experimental reactive wall at the Dover AFB National Test Site. This project is comparing the performance of alternative reactive materials for funnel and gate systems through a field-scale proof-of-principle demonstration. The process diagram is depicted in Figure II-9. Construction of the pilot-scale, permeable reactive barrier was completed during early January 1998. Extensive groundwater sampling and analysis was conducted during 1998 to determine the treatment efficiency of the funnel and gate system. Thus far, the system is effectively destroying the contaminants in the groundwater as it flows through the gates. Groundwater monitoring will continue in FY99 in an effort to better understand the longevity of the reactive material. This effort is being conducted by the EPA and the Air Force Research Laboratory.

Compliance Accomplishments

Monitoring and Measurement

Hazardous air pollutants (HAPs), including volatile organic compounds (VOC) and oxides of nitrogen (NO_X) and metals, are emitted from many DoD and DOE operations and the Clean Air Act Amendments (CAAA) require monitoring of these air pollutants. To reduce the cost (in millions of dollars) associated with chemical analyses of these air emissions, DoD is seeking alternatives to the traditional sample and analysis methods used to meet the current compliance monitoring requirements. SERDP currently is funding two projects developing two distinctly different monitoring approaches for DoD's HAP continuous monitoring requirements; in-situ monitoring and long-range monitoring by remote sensing.

The SERDP project, **Development and Integration of Laser-based Sensors for VOC/NO_X and Metal Emission Monitoring (CP-1060)**, was established to develop an in-situ monitoring approach with near real-time analysis of a wide range of species (metals and gases) for a variety of emission sources (mobile and stationary). The objective for monitoring VOCs/NO_X is to develop instrumentation that has the ability to detect broad classes (large and small molecules) of vapor-phase effluents at high sensitivity and over a wide spectral range. For metal measurements, the instrument must be able to detect multiple elements in both gas and aerosol phases at the low ppm to ppb range in a relatively short time frame, as compared to current methods which require days.

In FY98, an infrared photoacoustic spectrometer based on a novel laser technology, quasi-phase matched periodically poled lithium niobate (PPLN), was developed to monitor gas phase pollutants (i.e., VOCs and NO_X). The infrared (IR) spectrometer for monitoring gaseous effluents has demonstrated high sensitivity

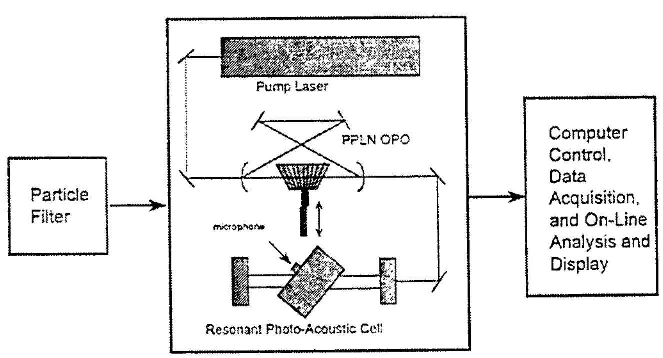

Figure II-10. Infrared Photoacoustic Spectrophotometer Schematic

measurements (10 ppb) of VOCs. Figure II-10 shows a schematic of the combined VOC/NOX emissions monitor using the photo-acoustic spectrometer.

For metals monitoring, a portable measurement system using a laser-induced plasma spectroscopy (LIPS) technique is being developed. The LIPS incorporates a compact pulsed laser, gateable micro-spectrometer, and an aerosol-beam focusing design. Substantial progress on an optimal system configuration for the LIPS (metal monitoring system), using a nanosecond laser, was achieved in FY98. These systems, when fully implemented, will allow near real-time analysis and in-situ monitoring of a wide range of species at relatively higher sensitivities than is currently attainable.

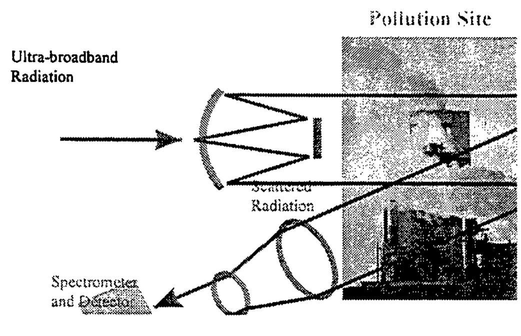

Figure II-11. Ultra-broadband Remote Sensing

The **Detect and Identify Multiple Hazardous Air Pollutants (HAP) at Extended Distances (CP-1061)** project was established to develop a long-range monitoring approach using remote sensing. Specifically, the project is using active remote sensing with ultra broadband (UB) radiation to provide real-time ranging and identification of HAPs at extended distances. A schematic of the ultra-broadband radiation concept is shown in Figure II-11. Significant progress was made in FY98 in generating the UB radiation. UB radiation was generated in fused silica optical fibers producing a spectrum that extends to more than 1.3 microns. More efficient UB radiation generation in longer wavelength regions was achieved by Raman shifting. All of these accomplishments allowed for experiments to be conducted to study the adsorption spectroscopic properties of atmospheric gases using broadband radiation.

"End-of-Pipe" Reduction

DoD has a growing need to control the emission of NO_X and HAPs including VOCs at its installations. These emissions frequently are episodic and variable with respect to the types of constituents and their concentrations. Existing control technologies have significant drawbacks, including not meeting the current and expected restrictions on emissions of NO_X/HAPs/VOCs. Without new technologies, the curtailment of missions, closing of facilities, and assessment of fines are real possibilities.

Non-thermal plasma (NTP) technologies show promise for addressing current and future needs to reduce or remove NO_X/HAPs/VOCs. However, reactor designs are energy intensive and it is necessary to identify ways to reduce the energy and power requirements. In response to this need, under the **Non-Thermal Plasma Technology for Reduction of Atmospheric Emissions (CP-1038)** project, a reactor system was designed and constructed that, when combined with a laser-diagnostic technique, allows the in-situ measurement of active species concentrations in the non-thermal plasma. In FY98, a lab-scale NTP reactor and associated fast-pulse electrical drive circuit was designed and constructed. The effectiveness of the process is being investigated using surrogate gas mixtures characteristic of exhaust-gas streams of concern to the DoD and to investigate the possibility of improving this effectiveness.

Treatment of Hazardous Wastes

Energetic Materials

DoD produces unique hazardous waste streams as a result of the production of munitions. These highly variable waste streams include smokes, dyes, riot control agents and chemical warfare materials. Because of the highly reactive nature of these waste streams and their byproducts, incineration has not been a viable treatment method. As an alternative to incineration, supercritical water oxidation (SCWO) provides high reaction rates at moderate temperatures at which harmful nitrogen oxides do not form.

SCWO development hinges on successful engineering of reactors that can meet long-term equipment reliability goals that are threatened by the formation of deposits (scaling) and corrosion of reactor materials. Successful reactor designs depend on an accurate understanding of the reaction kinetics of typical feed materials. The **Kinetics of Supercritical Water Oxidation (CP-364)** project, has successfully developed a fundamental model of oxidation kinetics in supercritical water. The application of this model has resulted in the efficient design of an autothermal feed system for SCWO waste treatment reactors (see Figure II-12) which permits safe operation with varying feed streams. This SERDP project was completed in FY 1998.

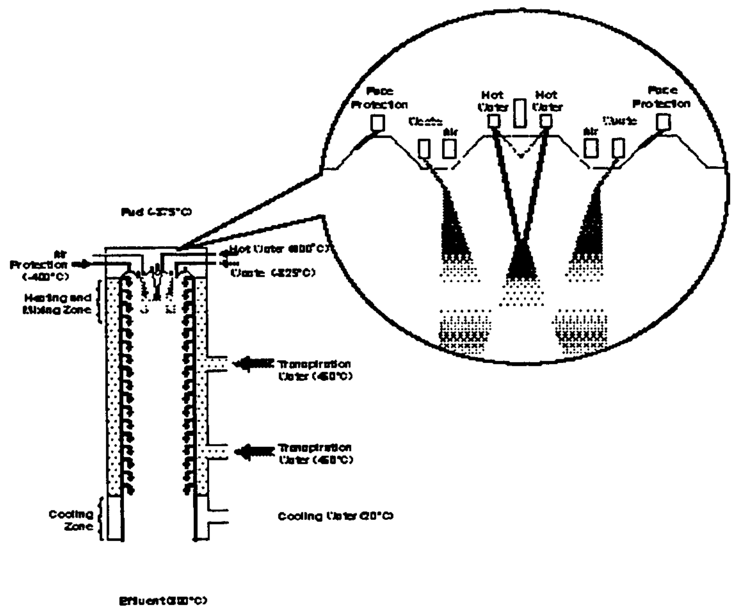

Figure II-12. Diagram of a SCWO Reaction Wall

Lead-Based Paint

In the past, the DoD used lead-based paint to cover steel structures and buildings that total approximately 4 billion square feet. Current removal methods for hazardous paint that contain lead, chromium or cadmium all rely on chemical stripping, abrasive blasting, vacuum assisted power tools, and high intensity and excessively noisy xenon lamps (Flashjet). These methods are time-consuming and create large quantities of hazardous waste. Most of these methods also require containment structures for environmental and worker protection. In order to comply with EPA and OSHA requirements, DoD needs a cost-effective technology to remove, characterize, and dispose of sources of lead hazards, such as deteriorating lead-based paint, from its facilities.

As part of the **Lead-Based Paint Hazard Mitigation (CP-521)** project, a microwave assisted process has been successfully demonstrated as a viable and environmentally sound method of lead based paint removal. The microwave assisted removal process applies a mixture of microwave coupling compounds (susceptors) with materials which react with and sequester the lead in the paint. Susceptor materials, such as graphite or iron oxide can reach temperatures up to 1000°C in less than a minute when exposed to microwaves (800 watts). The paint debonds from the substrate when heated with the microwaves. The resulting material is a cement-like clinker which is easily removed and is classified as non-hazardous, as can be verified by the EPA's Toxicity Characterization Leaching Procedure (TCLP). The microwave technique was patented by USACERL (US Patent No.5,268,548, A. Kumar).

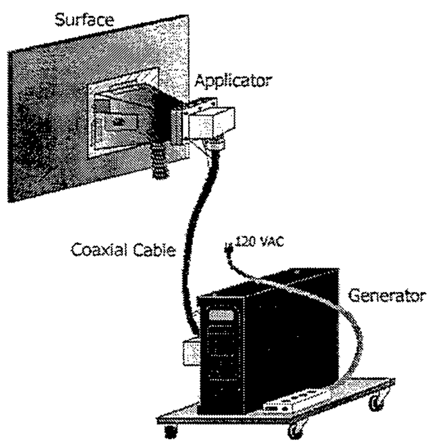

Figure II-13. CERL Portable Microwave Paint Removal System

In FY98, two design approaches for the microwave paint removal system were fabricated and used in the laboratory to remove lead-based paint. A proof-of-principal field test of microwave paint stripping was performed on an Army building near Lexington, Kentucky, in December 1997. Both microwave systems (Figure II-13) were used successfully to remove lead-based paint from an interior wood door and wood sill. The lead levels on the wood were dramatically reduced on the areas stripped, with removal rates similar to those achieved in laboratory experiments. Laboratory studies continue to attempt to optimize the efficacy of the microwave susceptors and chemical stabilizers to make the paint waste non-hazardous.

Incineration

Technologies for solid and liquid waste destruction in compact incinerators for marine applications are being developed as part of the **Compact, Closed-Loop Controlled Waste Incinerator (CP-34/887)** project. This project focuses on active combustion control to achieve significant reductions in emissions and increases in destruction efficiencies under realistic conditions in compact afterburner designs (Figure II-14).

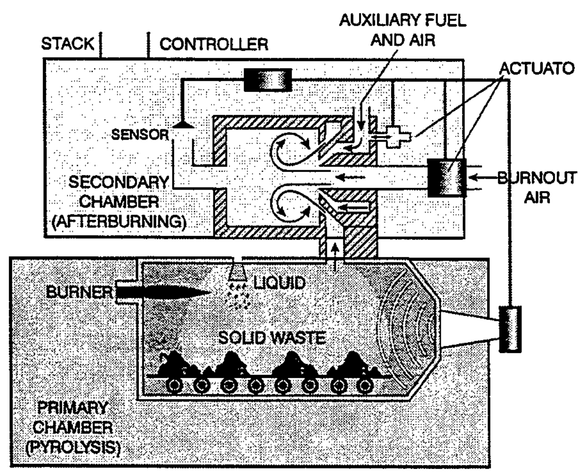

Figure II-14. Schematic for Primary and Afterburner in the Compact Waste Incinerator

Continued demonstrations conducted in FY98 confirmed that resonant acoustics can significantly increase the throughput of solid waste. Additionally, use of the active-control process can enable a reduction in afterburner size. The most recent developments using a new compact afterburner design with hot, sooty, pyrolysis gases resulted in no visible emissions remaining and carbon monoxide levels as low as 32 ppm, with NOX levels of 35 ppm for a residence time of about 62 ms. Adaptive control strategies were evaluated to minimize carbon monoxide emissions (corresponding to maximum destruction efficiency). The closed-looped control system was highly successful in optimizing the afterburner performance.

Systems Approach

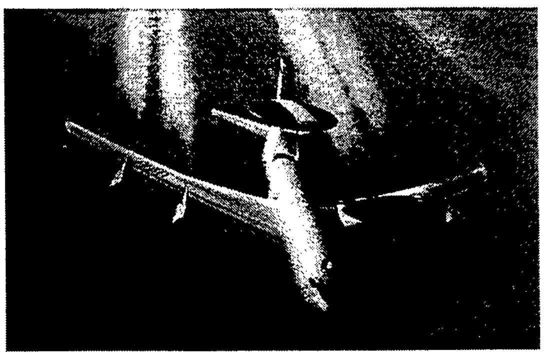

Figure II-15. Emissions from Air Force Aircraft Require Emissions Control Technology

In addition to evaluating DoD's compliance needs on a case-by-case basis, DoD also recognizes the need to implement strategic planning across all of its installations to ensure consistent and quality compliance programs. This type of systems approach evaluation reduces man-hours and expenses involved in selecting and implementing individual compliance programs and allows for consistent cost-effective control and mitigation techniques. In response to this need, the **Emission Reduction Planning Model (ERPM) Software (CP-175)** project developed a systems analysis software tool that combines air quality impact assessment techniques with rule-based expert algorithms to optimize compliance strategies. The ERPM software integrates an emission-dispersion database and expert decision system to aid environmental planners and air pollution managers in reducing hazardous air pollutant emissions at Air Force and Army installations. A library of data and analysis algorithms contains air pollution related information (including air emission inventories), provides control device cost estimates and applicability grading, calculates potential and actual emissions, estimates emission rates for many DoD source categories using EPA-developed emission factors, and includes alternative compliance strategies. The ERPM software was completed in FY98. Figure II-15 shows a typical Air Force aircraft for which an emissions control assessment can be made with ERPM.

Conservation Accomplishments

Ecosystem Management Initiative

The overall goal of Ecosystem Management is to maintain and improve the sustainability and native biological diversity of terrestrial and aquatic, including marine, ecosystems while supporting DoD mission readiness (Figure II-16). The **SERDP Ecosystem Management Project (CS-1114)** focused on two primary objectives: (1) translate the outcomes of the 1997 Ecosystem Management Scale Research Workshop into a potential sequence of research initiatives that respond to major themes from the workshop

and provide a "framework" of improved understanding about ecosystem processes on military lands and (2) identify the initial site to undertake these research initiatives.

Figure II-16. Ecosystem Management Research Is Being Used to Maintain Mission-Readiness While Protecting Endangered Species Such as the Red Cockaded Woodpecker.

The research initiatives included the conducting of ecosystem research and monitoring activities relevant to DoD requirements and addressing opportunities to facilitate the integration of results and findings of research into DoD ecosystem management practices. From the Workshop, four areas of research were identified to be accomplished as part of this project: (a) identify indicators of ecosystem status including its health and signals of change; (b) identify ecological thresholds such as minium habitat and population sizes along with species diversity that permits ecosystem recovery; (c) explore the role of biogeochemical cycle manipulation to promote biodiversity and recovery; and (d) establish the importance of spatial and temporal scales in the development and maintenance of ecosystems that may be at risk as a result of military operations.

The southeast U.S. region was selected as the area where the DoD has a large interest and a desire to look at ecoregional issues from the perspective of a large region dominated by private land holdings with several large military installations. Also the extensive "ecosystem related" constraints that have been experienced by military installations throughout the southeast relating to mission use and future mission capability.

Fort Benning in southeastern Georgia was selected as the candidate installation for the following reasons: (1) the Fort Benning long leaf pine ecosystem is representative of a number of bases and installations in the Southeast. (2) the high interest and support for applied research in ecosystem management from installation Operations and Environmental chains; (3) the diversity of mission uses and impacts; (4) extensive efforts already underway with an Installation Natural Resources Management Plan that involves interagency partnering, ecosystem planning, and multi-use considerations; (5) extensive environmental databases in place including Land Condition Trend Analysis (LCTA); and (6) the importance to the Army training mission and the likelihood of a long term investment of resources in the installation.

Military Impacts on Land, Air, and Marine Environments

The U.S. Army alone has 11 million acres of training lands with annual land repair and maintenance costs of $56 million. Soil erosion, along with concomitant sediment deposition and siltation of waterways, is a serious problem on military training and testing lands where the soil and vegetation are frequently disturbed (Figure II-17). In addition, the savings in dredging costs in downstream areas would most likely exceed even this estimate.

Most erosion and deposition models historically have been developed for agricultural lands and consider landscapes to be a series of homogenous, planar farm fields. Such simplistic approaches cannot account for the complex topography on military lands. The U.S. Army Engineer Research and Development Center and the University of Illinois extended traditional soil erosion simulation capabilities to more complex landscapes in the **Digital Terrain Modeling and Distributed Soil Erosion Simulation/Measurement for Minimizing Environmental Impacts of Military Training (CS-752)** project. Their modeling and simulation efforts were originally validated on the Scheyern Experimental Farm in Germany. When the study began, approximately 21 percent of the study area was planted with grass and the remainder was cultivated. This land-use pattern resulted in severe erosion and significant sediment discharge leaving the watershed. The farm managers implemented traditional "best land management practices" consisting of wide grassed buffers at the valley bottom. By strategically placing a minimum grass cover of 19 percent in areas of highest erosion potential, the model accurately predicted virtually all sediment loading could be eliminated with a substantial cost savings. These results demonstrate the potential use of the model to reduce soil loss and sediment loads dramatically. The Army is currently conducting additional land management demonstrations and validations at Fort Hood, TX, and the Combat Maneuver Training Center at Hohenfels, Germany.

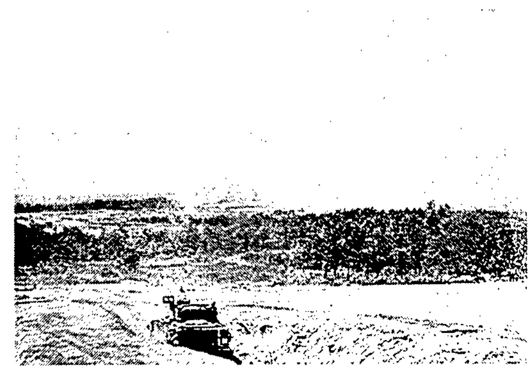

Figure II-17. Erosion Caused by Tank Maneuvers.

Training and Testing Impacts on Marine Mammals

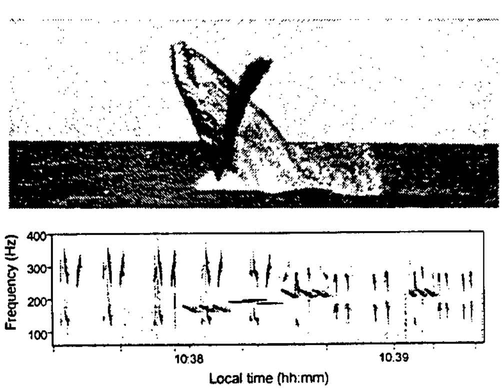

Figure II-18. Upper Panel: Humpback Whale Breaching off of Hawaii. Lower Panel: Spectrogram of Two-Minute Segment of Humpback Whale Song, Overlapping 42-Second Low Frequency Active Sonar Transmission.

Large whales emit low frequency sounds for sensing and communication and other marine mammals dive deeply into the sound conducting channel and may be at risk from manmade low frequency sounds. At present there is not an adequate understanding of the effects of manmade sound in the marine environment. Cornell University conducted research to quantify the responses of humpback whales to experimental sound levels. The results from **Marine Mammal Responses to Low Frequency Sound (CS-1069)** indicate no immediate obvious response by individual whales during exposures to received level as high as 130 dB (Figure II-18). There was no noticeable change in the number and density of animals, the number of singers or the behaviors of animals over a period of several months. There was only one consistent statistically significant response: the distance between successive surfacings for a whale increased with increasing received sound level. However, the effect

explains less than two percent of the total variation in this measure and the response is not considered biologically significant.

Whales are at the apex of a chain of food productivity that covers hundreds of miles within a few short days. Their migrations regularly take them from the surface to the depths of the ocean over home ranges that may encompass areas as large as continents. It is not unusual for a whale to travel one thousand miles in a week, simply as a routine change between feeding sites. Under these conditions it has been difficult to determine what effect, if any, a given human activity has had on a population of whales responding to dynamic ocean phenomena. The U.S. Navy's Integrated Undersea Surveillance System (IUSS) provides a unique resource to monitor the presence, distribution, and relative abundance of several endangered and protected marine mammals, with the greatest emphasis on large baleen whales. With leveraged funding from the SERDP **Whale Monitoring Using IUSS (CS-48)** project, three decommissioned IUSS arrays were reactivated and used along with other active acoustic sources to monitor the movements of whales in areas of the North Atlantic and Pacific Oceans. The use these acoustic monitoring technologies, along with traditional surface visual monitoring, and new Navy-sponsored techniques for radio and satellite tracking of individual animals provided a combined unique environmental monitoring scheme. This monitoring has allowed the Navy to continue to its sonar and blast testing and other operations in areas normally frequented by whales. In addition, the SERDP funded research provided the means to both monitor the large scale areas within which whales live and at the same time provide in-depth characterization of focal areas where whales may be affected both by large scale natural phenomena (such as plankton blooms and changes in currents) and localized human activities that might produce similar effects.

Natural Resource Decision Support

Ecological models at three levels were developed and integrated to assist military operational trainers and land managers at Fort McCoy, Wisconsin. These models are used in managing endangered and threatened species while retaining the ability to continue training operations species as a part of the **Ecological Modeling for Military Land Use Decision Support (CS-758)** project. A habitat model based on soil type, topography, land cover, and forest density is being used to evaluate all of Fort McCoy with regard to suitability for wild blue lupine, the host plant for larvae of the endangered Karner blue butterfly (KBB) subpopulations (Figure II-19). This habitat model will be used to guide future monitoring efforts for the butterfly and to inform decision makers on how land use actions, such as development of tank movement corridors, will impact the butterfly's habitat. Linked to the habitat model is a metapopulation model of the butterfly that can be used to identify where training and testing are likely to improve or degrade most significantly the subpopulations required to be managed. Together these two models provide information about the location of sites of management concern and

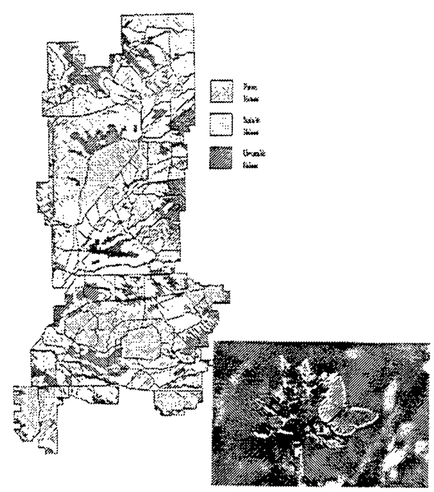

Figure II-19. Habitat Map of Fort McCoy Developed for the Protection of the Karner Blue Butterfly (inset).

suggest military training regimes that are compatible with the preservation of the endangered butterfly. The models provide a scientifically valid basis for making decisions about intensity, timing, and location of military use of the land and about apportionment of scarce monitoring and restoration resources. As such, these models will assist Fort McCoy in meeting agreed upon conservation goals outlined in their KBB Draft Recovery Plan. In addition, this approach provides a scientific basis to allow Fort McCoy to interact effectively with the U.S. Fish and Wildlife Service and the Wisconsin Department of Natural Resources in identifying off-base activities that may impact butterfly populations on Fort McCoy.

Pollution Prevention Significant Accomplishments

"Green" Energetic Materials and Processes

SERDP continues to play a significant catalytic role in leveraging the Services research and development initiatives to find greener, better, and cheaper alternatives to existing DoD conventional munitions. These munitions are generally grouped as solid rocket propellants, gun propellants, explosives, and pyrotechnics. General environmental problems associated with munitions include the need to eliminate toxic ingredients (such as chromium) and volatile organic compounds (VOC) and reduce wastes generated during their production and use. SERDP has and continues to play a significant role in the development of alternate materials, processes, and modeling tools as well as technologies to recycle and reuse conventional munitions during the demilitarization cycle. Examples of SERDP developed greener energetics materials that are being demonstrated include binder material such as: thermoplastic elastomers (TPE) and new propellants and explosives such as, tri-nitro azetidine (TNAZ), and ammonium dinitramide (ADN).

Laser Ignition

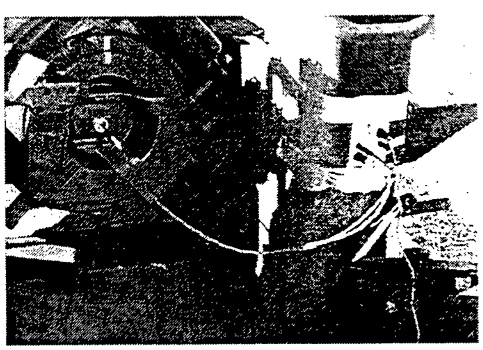

Figure II-20. Diode Laser Array on Towed 198 Howitzer

FY 1998 will be the final year of SERDP funding for a highly successful project, **Laser Ignition to Replace Chemical Ordnance Igniters for Propulsion (PP-680).** This project developed a laser ignition system to replace lead-based compounds used in primers for the Crusader Advanced Solid Propellant Armament (ASPA) system Howitzer (155mm XM297 cannon). It is estimated that 375 tons of primer and igniter material are used each year by DoD for artillery rounds. The Crusader program has selected the laser ignition system as the main igniter and is executing a successful transition of this technology for large caliber ammunition. While developed for environmental purposes, laser ignition resulted in a higher rate of five and increased soldier safety in the Crusader Weapon System. The laser also has been developed for retrofit to the M109A6 Paladin self-propelled 155-mm howitzer and, for this purpose has been demonstrated successfully at Fort Sill and to the government of Kuwait. In FY 1998, this project also successfully fired 20 rounds using the laser in an AH-64 Apache helicopter 30 mm automatic cannon which has a requirement for radio frequency insensitivity and no

electromagnetic interference to avoid accidental discharge. This is the first time that a medium caliber weapon has been fired with the laser. Figure II-20 shows the Laser Ignition System developed for the 155 mm Crusader Howitzer gun.

Recycling Propellants

SERDP sponsored work on **Theoretical Chemistry: An Emerging Practical Tool in Army Research** was awarded Best Technical Paper at the 21st Army Science Conference in Advanced Propulsion and Power Technologies

The SERDP funded project, **Recycling Propellants in Supercritical Fluids: Novel Computational Chemistry Models for Predicting Effective Solvents (PP-695)** is developing molecular models for use in computer simulation to determine the conditions that will result in maximum extraction of reusable ingredients from waste energetic materials. In FY 1998, this SERDP-sponsored work was awarded the Best Technical Paper at the 21st Army Science Conference in the Advanced Propulsion and Power Technologies section of the Conference. The title of the paper was *Theoretical Chemistry: An Emerging Practical Tool in Army Research*. This paper presented the results on four aspects of modeling energetics materials which are aimed at developing a fundamental understanding of their basic properties. These models currently are being used to guide the demilitarization/recycling of DoD energetics being supported by SERDP and also will be used in a new SERDP effort on Green Energetics Propulsion Modeling. Figure II-21 shows a model of RDX in polar modified supercritical CO_2.

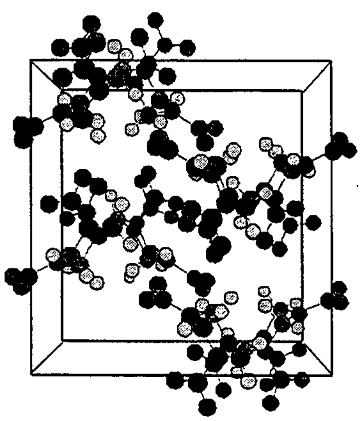

Figure II-21. Model of RDX Molecule

"Green Bullet"

In FY 1998, the SERDP-sponsored project **Elimination of Toxic from Small Caliber Ammunition (PP-1057)** has completed preliminary evaluation of tungsten as environmentally friendly alternative material for lead containing projectiles in small caliber ammunition. The ultimate goal of this project is to obtain technical solutions for producing non-toxic small caliber ammunition which will meet U.S. and NATO performance standards for all calibers (5.56mm, 7.62mm, 9mm, .50 caliber). This project will focus on eliminating toxic components in the projectile core and primer and in the manufacturing processes. Figure II-22 shows the environmental toxics associated with a small caliber ammunition. This project is evaluating Metastable Interstitial Composites (MIC) as alternatives to current

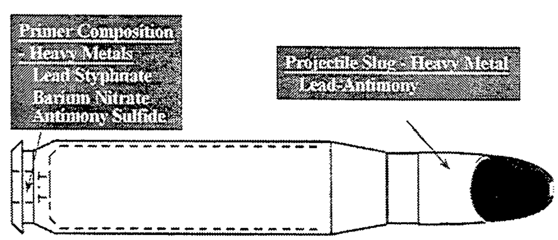

Figure II-22. Hazardous Materials in Small Caliber Ammunition

species that are exothermically reactive with each other. Projectile core material presently use a lead-antimony mixture - lead being a major leachate problem. By using other materials such as tungsten, the projectile characteristics are preserved with no leachate problems.

Modeling and Monitoring (Measurements)

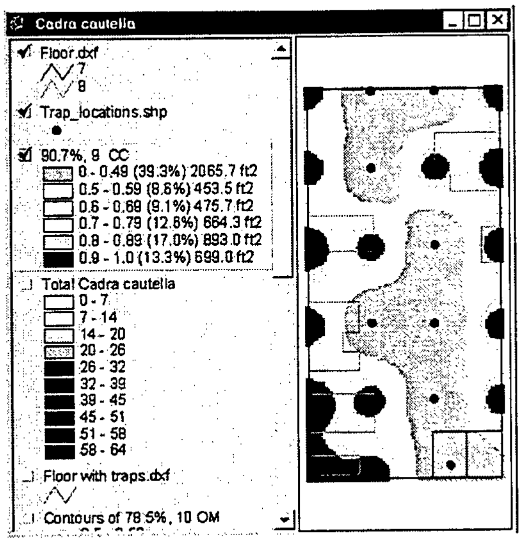

Figure II-23. Probability of Locations for Insect Pests Within a Building Derived from Precision Monitoring Using Traps

Measurement, monitoring, and modeling are effective pollution prevention tools used to assess and predict environmental impacts. With the significant advances in numerical modeling and certain specialized technologies such as geographical information system (GIS), it is now possible to define and predict life-cycle impacts and perform risk analysis on a variety of environmental parameters at DoD and DOE facilities. In FY 1998, SERDP, in partnership with the United States Department of Agriculture (USDA), in the **Pesticide Reduction Through Precision Targeting (PP-1053)** project, successfully developed innovative tools to reduce pesticide use and pesticide-related risks in an integrated pest management strategy using "precision targeting" and verifiable comparative risk reduction. This risk reduction model assesses risks and provides a comprehensive, verifiable, and documentable spatial illustration using GIS that displays levels of risk (contour lines of equal probabilities) at all locations within the area of interest. Subsequently, proposed interventions with emerging least-toxic technologies can be evaluated and selected and a minimal amount of pesticide can be applied according to a precision targeting map (Figure II-23).

DoD currently uses approximately one million pounds of pesticide (active ingredient) annually, excluding pesticides used during major deployments, to combat vector-borne diseases and the destruction of food, material supplies, and facility structures caused by pests. Excessive pesticide use causes significant impacts on the environment and human health (e.g., groundwater contamination and chronic and acute toxicity). The application of this tool is projected to reduce the pesticide use by 40 to 80 percent resulting in both direct and indirect savings to DoD. In FY 1998, Beta tests of this SERDP sponsored software/hardware tool conducted by the U.S. Army Center for Health Promotion and Preventive Medicine (CHPPM) at the Ft. Meade (MD) golf course for the treatment of the June Beatle larvae indicated that pesticide use can be reduced by 67 percent resulting in $136 in possible labor and pesticide savings per fairway. Figure II-31 shows GIS tools developed for computerized monitoring techniques for mitigating Pharaoh ants at the hospital and other locations at the Jacksonville Naval Air Station.

Environmentally Acceptable Coatings

In recent years, many Federal and state regulations have set strict limits to minimize air pollutant emissions. In Southern California, an area containing many industries critical to aerospace, the South Coast Air Quality Management District (SCAQMD) Rule 1124 allows adhesive primers a maximum emission of 240 grams/liter of VOCs. An extension for compliance has been granted to the industry until the year 2002. However, at that time, the new materials must be fully implemented and further extensions are not likely. Many other regulators, including the Federal government, are legislating limits for hazardous air pollutants (HAPS). For example, OSHA has proposed a permissible exposure limit (PEL) of 0.5 $\mu g/m^3$ for chromium. In order to meet or exceed the legislative targets, many commanders of DoD field units have banned or severely restricted the use of chromates and VOCs at their installations.

As a result of these new regulations, the increased costs of hazardous waste disposal, as well as the increased awareness and costs of employees' health and safety, it is imperative that DoD develop and use environmentally acceptable coatings and low-VOC/nontoxic surface treatments/primers for structural adhesive bonding and sealant applications.

In FY 1998, SERDP made significant contributions to solve major environmental problems facing the DoD depot and field level operations. SERDP adopted a two-pronged approach in developing environmentally acceptable coatings. One approach is to develop DoD unique coatings that are VOC- and HAP-free that still meet unique military requirements. In particular, Chemical Agent Resistant Coatings (CARC) have no commercial equivalent. The primary deficiency in current CARC is the excessive levels of VOC in the polyurethane topcoat. At current production levels, 10 million pounds of VOCs are emitted per year into the atmosphere from CARC painting operations. The existing CARC topcoat has a VOC content of 3.5 lb/gal, whereas local requirements are as low as 1.8 lb/gal.

Low-VOC CARC


Figure II-24. Tactical Military Vehicles Such as Tanks Will Be Coated with CARC

To date, SERDP has been very successful in developing environmentally acceptable coatings. Specifically, the SERDP-sponsored project **Low VOC Chemical Agent Resistant Coatings (CARC) (PP-1056),** successfully developed a water reducible low-VOC CARC formulation suitable for use on military equipment by all Services in all aspects of application, stripping, and disposal. This new CARC meets the goal of a maximum of 1.8 lb/gal VOC and is free of HAPs as defined by the Clean Air Act Amendments of 1990. An estimated four million pounds of VOC emissions will be eliminated with this new formulation, and equipment cost avoidance of $60 million and annual operating cost savings of $3 million are predicted at 12 DoD facilities. In FY98, the principal performer for this project, the Army Research Laboratory (ARL), received a patent (#5,691,410) for the

water reducible low VOC CARC formulation. This formula was optimized for all five Service colors and industry partners have manufactured initial quantities of each color (camouflage green, brown, black, desert tan, and Air Force green), required by the Services. Figure II-24 shows tactical military vehicles such as tanks that will be coated with CARC.

Sol-Gel Coatings

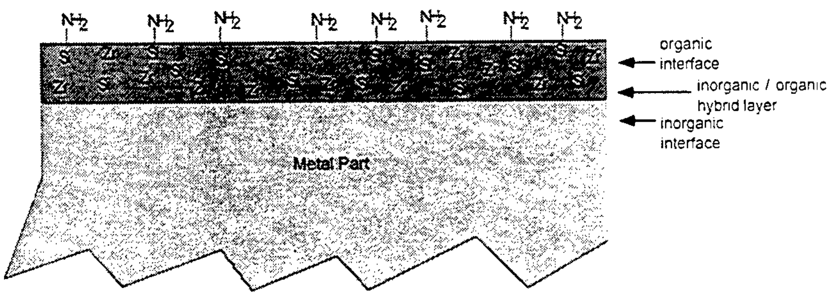

Figure II-25. Solution-Gelation (Sol-Gel) Concept

As part of the second approach, SERDP is leveraging multi-service research and development initiatives to develop primer free, environmentally acceptable next generation coatings. SERDP initiated research in FY 1998 to develop a next generation of coatings technology called solution-gelation (Sol-gel) materials and processes for aluminum, titanium, and steel bonding and the development of low-VOC sealant adhesion promoters/primers. Sol-gel has many applications such as anti-reflective coatings, scratch-resistant coatings, and gas membranes. However, the application of sol-gel for metal surface preparation/priming for bonding and sealing has not yet been explored. The SERDP project, **Sol-Gel Technology for Low VOC, Non-Chromated Adhesive and Sealant Applications (PP-1113)**, is developing novel processes that are non-chromated and primer-free and will eliminate ever increasing hazardous waste disposal costs associated with the application and removal of primers. Results of initial one-step (sol/primer mixture) testing using sol-gel chemistry with waterborne primer were promising for aluminum substrates. This formulation worked well on certain steel alloys during previous testing. Figure II-25 shows the concept of sol-gel chemistry.

The SERDP-funded project **Non Chromate Conversion Coatings for Aluminum Alloys (PP-673)** developed an alternative to sodium dichromate sealers currently used in the aluminum anodizing process for munitions, combat and tactical vehicles, and aircraft. An estimated six million gallons of wastewater are generated from these anodizing operations at DoD facilities annually. The trial test results demonstrated that the magnesium- and lithium-bearing sealant solution provided comparable, and in some cases, better performance levels. These tests were complemented with work by the National Center for Manufacturing Sciences (NCMS) using similar

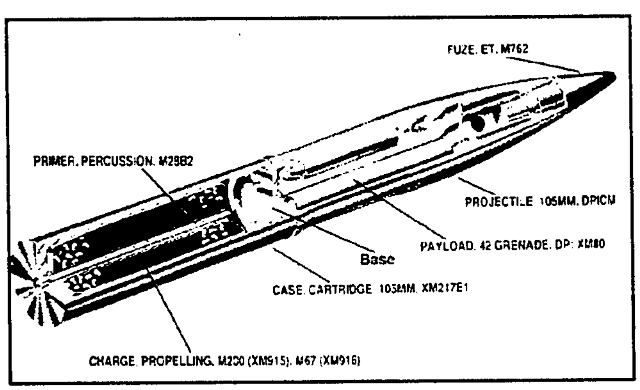

Figure II-26. Sealant Use in Artillery Rounds

sealers on other aluminum alloys. Eliminating the generation of chromium containing wastewater is expected to result in a more than $2 million savings in wastewater treatment costs. Figure II-26 shows the sealant use in artillery rounds.

Next Generation Fire Suppression Technology Program (NGP)

The production of Halon 1301 was banned by the 1987 Montreal protocol on substances that deplete the ozone layer. A SERDP umbrella project with government/industry/academia partnership which began in FY 1997 is part of the NGP for the replacement of Halon 1301 in DoD weapon systems. The goal is to develop and demonstrate by the year 2005, Halon alternatives that are easily retrofittable into currently fielded weapons systems. Figure II-27 illustrates the Fire Supression Flow Concept. NGP is divided into the following six fully-integrated technical focus areas, each with sequential and synergistic research elements (a total of 32 research elements):

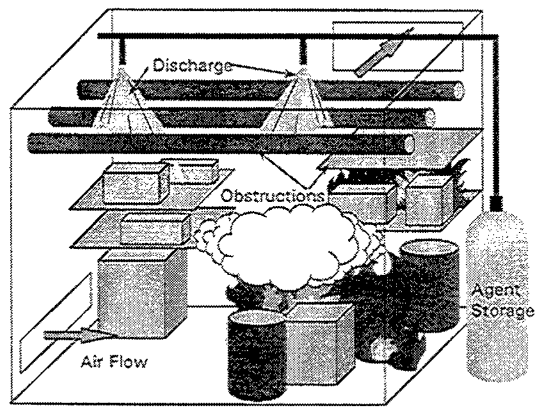

Figure II-27. Fire Suppression Flow Concept

1. Risk Assessment and Selection Criteria
2. Fire Suppression Principles
3. Technology Testing Methodologies
4. New Suppression Concepts
5. Emerging Technology Advancement
6. Suppression Optimization

Sixteen New Start projects were initiated in FY 1998. The NGP program now has its own web page (http://www.dtic.mil/ngp). Following are some of the significant accomplishments in FY 1998:

- A number of compounds containing phosphorus, iron, nitrogen, and bromine have been demonstrated to be at least as effective as Halon 1301 with little potential environmental impacts. These families of chemicals are being examined to identify members with other desirable properties, and studies of other chemical families are in progress.

- Assessment of the toxicity of candidates is being modified to include maximum realistic exposures to the chemicals. This may well allow reconsideration of some effective suppressants that were previously regarded as too risky.

- A new apparatus developed under the NGP can measure the effectiveness of gaseous, liquid droplet or mist, and (soon) powdered agents using only small samples. This enables quick examination of new, custom compounds with properties not previously accessible, such as liquids with high boiling points.

- Enhanced capability for monitoring the dispersion of the agent and the undesirable combustion products (e.g., HF) during quenching of fires in actual weapons systems is being used to identify new gelling agents for fire suppression.

III. PROGRAM DESCRIPTION

General

This section provides an overview of each of the SERDP Thrust Area Programs for FY 1998 and FY 1999 and planned FY 2000 initiatives for research. Topics include the goals of each Thrust Area, the environmental and operational drivers directing needed technologies, and the major areas of research and development (R&D) within each Thrust Area. Cross-references also are provided to each project with respect to subtopic categorization and completion status.

The SERDP Program contains the following four Thrust Areas: Cleanup, Compliance, Conservation, and Pollution Prevention. Each year the Program Office, with the assistance of the Technology Thrust Area Working Groups (TTAWGs) and Executive Working Group (EWG), determines the funding balance between these four Thrust Areas. Figure III-1 describes the distribution of funds to specific Thrust Areas for FY 1998 and FY 1999.

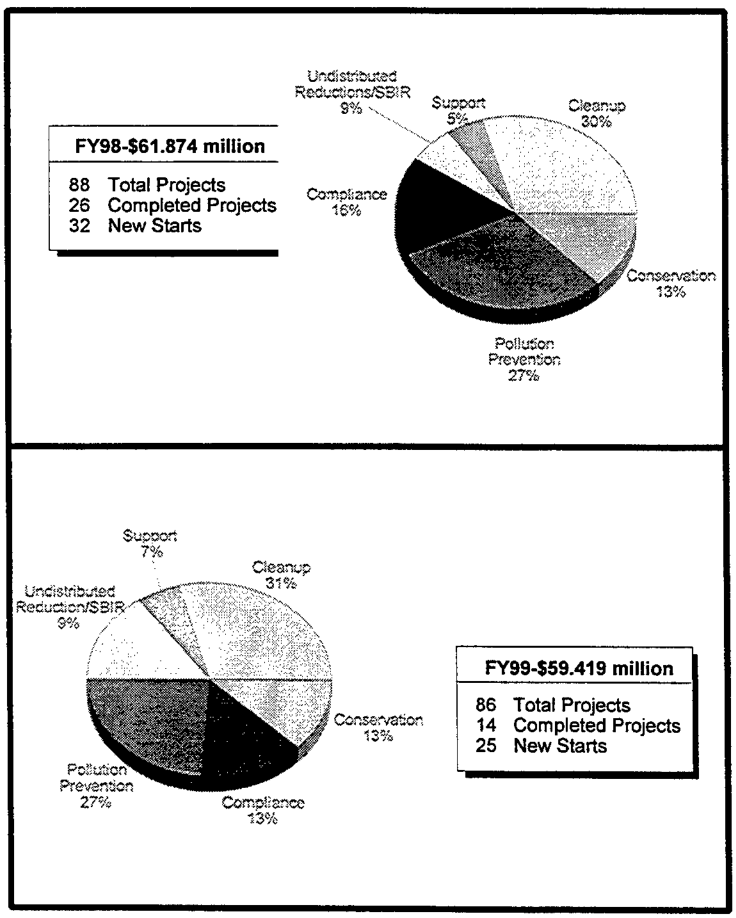

Figure III-1. SERDP Funding, FY 1998-FY 1999

Program Development

The SERDP FY 1998 Program was prepared in accordance with the established Congressional direction and further guided by policies provided by the SERDP Council. Participating SERDP organizations and their laboratories were asked to solicit proposals that responded to the high-priority defense environmental needs as stated by the Deputy Under Secretary of Defense for Environmental Security DUSD(ES). Each participating organization conducted its own internal down-select procedure and forwarded its best proposals to SERDP for consideration. SERDP's multi-agency TTAWGs were tasked with reviewing these submissions for technical merit and relevance as well as overall cost. All proposals selected by the TTAWGs were sent for review by the SERDP Scientific Advisory Board prior to Council approval.

The FY 1999 SERDP Program was developed during FY 1998 in order to expedite timely project funding. SERDP continues to strive to fund the highest quality research through open-competition. As a result, for the second year, the Executive Director, at the direction of the Council, issued an open solicitation for FY 1999 that encouraged direct submission of proposals by the non-Federal sector, in addition to the normal call for proposals to the Federal sector. Non-federal participants included industry, non-profit entities, and academia. The solicitation appeared in the Commerce Business Daily and resulted in submission more than preproposals, of which 60 were requested to submit full proposals. Each of the submitters responded to one of 15 Statements of Need (SON), as published in the FY 1997 version of this report, as well as three SONs developed by the SERDP Ecosystem Management Workshop (SEMP). Eleven out of 52 full non-Federal sector proposals were selected competitively for FY 1999 funding by the Council. This rate met the Council's goal for a 20 percent selection rate for full proposals submitted through the Broad Agency Announcement (BAA) process. From the Federal sector, 13 proposals were selected for funding out of a total of 88 proposals submitted. Summaries of these projects may be found in the list of FY 1999 New Start Projects within each Thrust Area description section and in Appendices A through D.

CLEANUP

Introduction

DoD and DOE must protect human health and the environment, reduce remediation costs, and provide timely cleanup. Cleanup goals for the DoD are to:

- Attend to imminent threats to public health and safety;
- Remediate all defense sites having a significant public health risk as quickly as feasible within the constraints of available resources; and
- Expedite transfer of Base Realignment and Closure (BRAC) sites and Formerly Used Defense Sites (FUDS) to future owners.

DoD and DOE have a legal obligation to meet the Federal, state, and local environmental protection and public health regulations. Both Departments own and operate thousands of installations, ranging from training bases to industrial production plants. Many of these installations have been operating for half a century or longer. During most of this time the agencies, like much of American industry, operated their facilities without full respect for the environment or an understanding of potential impacts.

Using today's technology, the cost to remediate DoD sites alone is estimated at $35 billion, and total cost of cleanup at current and former defense sites (including DOE sites) is projected to exceed $200 billion. Experience with past remediation technology development has demonstrated a significant return on investment. Defense environmental managers require cost-effective and timely remediation capabilities that focus on assessment, characterization, and treatment. Each DoD Service has submitted its User Requirements for Cleanup, which are prioritized in the DoD Environmental Technology Requirements Strategy. These requirements can be grouped into environmental concerns. Within the Cleanup Technology Thrust Area, the primary environmental concerns are the need to:

- Implement timely, effective, and affordable methods for site characterization, including detection of unexploded ordnance (UXO);
- Ensure the use of effective, affordable remediation technologies; and
- Comply with various Federal, state, and local regulations for site remediation.

These concerns are addressed by the Cleanup subthrusts and research areas as depicted in Figure III-2.

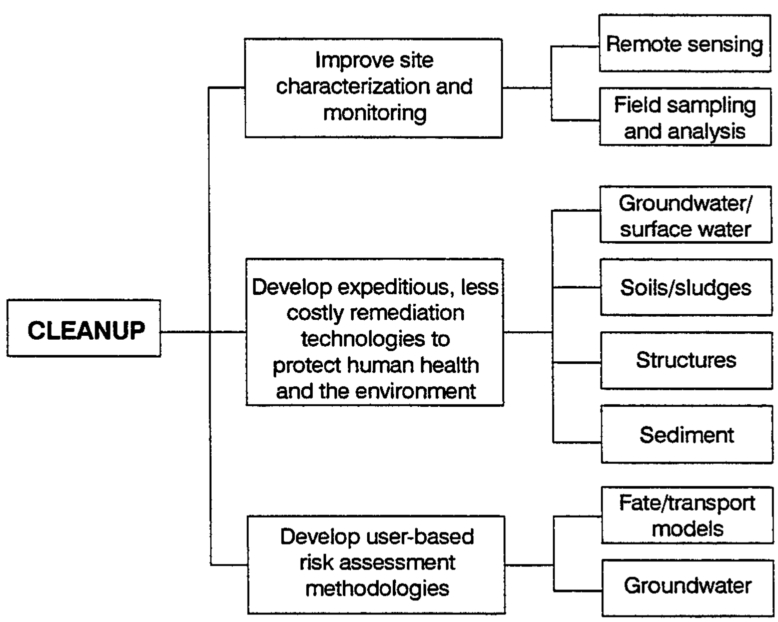

Figure III-2. Cleanup Taxonomy

Figure III-3 shows the FY 1998 and FY 1999 cleanup funding by subthrust area. For FY 1998, the Cleanup Technology Thrust Area received approximately 30 percent of the SERDP budget. While many defense cleanup situations will require that technologies be identified in the near-term, additional research in this area still can potentially provide the highest return on investment.

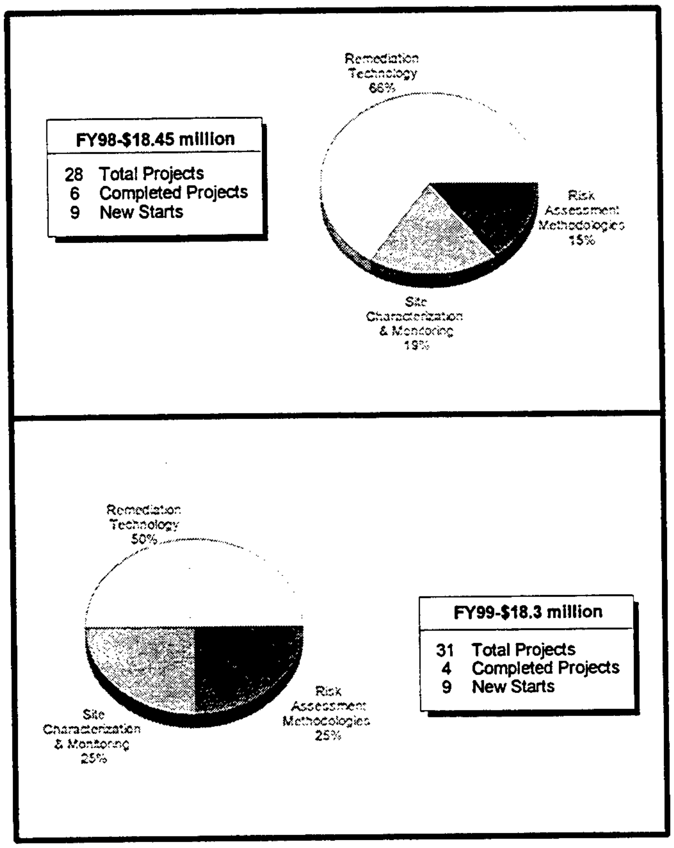

Figure III-3. SERDP Cleanup Funding, FY 1998-FY 1999

Principal Driving Requirements

The first subthrust area in Cleanup seeks to develop improved and less costly site investigation technology for locating and characterizing wastes. Within this subthrust, the location, identification, and remediation of UXO has been identified by the Services as the highest priority user need. It poses an enormous challenge to the effective cleanup of many DoD sites, primarily on land but also under water. Current estimates indicate that up to 11 million acres of land in the U.S. are suspected to contain UXO as a result of military training and weapons testing activities--6 million acres of UXO contaminated Army and Navy land, approximately 5 million acres on Department of Interior land, and at least 50 sites at sea. These lands represent a full range of terrains, vegetative cover, soil types, and geophysical characteristics. The

present cost, driven largely by the need to exercise extreme safety precautions, ranges from $1,500 per acre for surface UXO to at least $5,000 per acre for sub-surface ordnance.

Identifying and characterizing sites contaminated with chlorinated solvents is another significant issue to the DoD. Chlorinated solvents represent a class of contaminants that are detected at more DoD sites than any other contaminant group. Chlorinated solvents, predominantly perchloroethylene and trichlororthylene, have been used in massive quantities over the last four decades. Release of these liquids to the environment accounts for a significant portion of contaminated sites requiring cleanup. These contaminants have migrated through the subsurface and entered groundwater at more than 50 percent of the contaminated DoD sites. There is a comparable degree of contamination at DOE and private industry Superfund sites. Estimated annual costs exceed $500 thousand for containing and monitoring a single dense non-aqueous phase liquid (DNAPL) plume. Novel technologies to detect and characterize these plumes will go a long way to assist in reducing these costs.

Cleanup's second subthrust focuses on the need to develop expeditious, less costly remediation technologies. Remediation of subsurface contamination of both soils and groundwater remains a high priority at DoD facilities. Groundwater is mobile and can spread contamination off base. Therefore, this subthrust is directed primarily at developing innovative technologies to address groundwater remediation more effectively. Current groundwater treatment strategies typically employ pump-and-treat technologies which are expensive to operate and are very slow to achieve lasting cleanup. Major limitations to the use of conventional pump-and-treat technology relate to difficulties in extracting contaminants from source areas where non-aqueous phase liquids (NAPLs) exist. Furthermore, presently employed technologies applied in pump-and-treat, such as air stripping or activated carbon treatment, do not result in final destruction of contaminants.

The challenges facing those involved with the nearly 17,000 sites on DoD installations potentially requiring environmental clean-up include: (1) distinguishing those sites that pose significant environmental risks from those that pose little risk; (2) prioritizing contaminated sites by the degree of risk posed; (3) quantifying the risks at each site; and (4) developing appropriate remedial actions and cleanup goals. Development of improved techniques for risk assessment, which provides a logical framework for making such decisions, is a DoD priority and the focus of this third Cleanup subthrust. The effectiveness of existing methods will be expanded by research directed at problems particularly evident at DoD installations.

Leveraging with other defense science and technology programs and industry, the Cleanup Technology Subthrust Area focuses on the following R&D objectives:

- Develop reliable and cost effective means to identify, assess, and clean lands and underwater areas (inland, estuarian, and marine) contaminated with unexploded ordnance;

- Develop investigation methods and technologies that are capable of locating and characterizing wastes in a timely, cost effective, and quality manner;

- Develop innovative, compliant technologies that reduce remediation costs for sites containing explosives, propellants, fuels, solvents, heavy metals, organic contaminants, and other inorganic contaminants;

- Facilitate transfer of cleanup technologies to field use. This includes, but is not limited to encouraging the use of the National Environmental Technology Test Sites;

- Develop cost-effective methods and tools to determine fate, transport, and effects of significant defense-related contaminants; and

- Develop risk-based modeling and simulation methods for hazard assessment and establishing cleanup priorities and scientifically defensible levels.

- Develop scientifically defensible EAEs for DoD chemicals of concern including chlorinated organics, organics associated with explosives, and heavy metals, to facilitate risk-based cleanups at DoD sites.

Cleanup Program

The following list reflects FY 1998 completed projects and projects continuing into FY 1999. Also included are titles of projects that begin in FY 1999. Complete descriptions of all of the projects for FY 1998 and FY 1999 may be found on the pages referenced in Appendix A - Cleanup Project Summaries.

Subthrust 1 - *Improve Site Characterization and Monitoring*

FY 1999 New Start Projects

Subthrust 2 - *Develop Expeditious, Less Costly Remediation Technology*

FY 1998 Completed Projects

FY 1999 Continuing Projects

FY 1999 New Start Projects

Subthrust 3 - *Develop Risk Assessment Methodologies*

Other

FY 2000 Cleanup Initiatives

In-Situ Treatment Technologies continues to be a major research priority in the Cleanup Thrust Area. To this end, an FY 2000 SON has been issued. **In-Situ Treatment Technologies for Ammonium Perchlorate Contaminated Groundwater**, ammonium perchlorate is used as an oxidizer component in solid propellant (fuel) for rockets, missiles, and fireworks. Recent advances in the analytical detection capability for low concentrations of perchlorate, from 400 to 4 parts per billion (ppb), have led to the discovery of the chemical at various manufacturing sites and some drinking water supply wells of communities in California, Nevada, and Utah. The focus of this SON is to develop abiotic and biotic approaches for the cost effective, in-situ treatment of groundwater contaminated with ammonium perchlorate at DoD, DOE, and defense contractor facilities. The development of abiotic or biotic in-situ methods for treating large volumes of groundwater contaminated with perchlorate is necessary to address this national concern adequately.

A second FY 2000 proposed area of new research is **Bioavailability and Long-Term Stability Issues Associated with Metals in Soils**. During the last 30 years, the science of environmental risk assessment and understanding of the fundamentals of the fate of metals in soils and the environment have greatly improved. There are nearly 17,000 sites on DoD installations potentially requiring environmental cleanup. The challenges facing those involved in cleanup include distinguishing those sites that pose significant environmental risks from those that pose little risk, prioritizing contaminated sites by the degree of risk posed, quantifying the risks at each site, and developing appropriate remedial actions and cleanup goals where appropriate. The primary emphasis of this SON is to develop a better fundamental understanding concerning the bioavailability and long-term stability issues associated with metals in soils. This need seeks

a greater knowledge of the science regarding the behavior/chemical state of metals in soils and improved measurement techniques to assess bioavailability and address the technology gaps that adversely influence risk assessments and remediation of metals contaminated soils.

The last FY 2000 proposed new initiative is entitled **Establish Better Understanding of Aerobic and Anaerobic Transformation of cis-Dichlorethene (cis-DCE) and Vinyl Chloride (VC)**. VC and cis-DCE are basic byproducts of the biodegradation of the chlorinated solvents perchloroethylene and trichloroethylene. Currently there is an inadequate state of knowledge about aerobic and anaerobic metabolism of cis-DCE and VC. It is difficult to predict the time required for the concentration of the toxic intermediates to reach an environmentally acceptable endpoint. This SON seeks innovative laboratory-and bench-scale research approaches that will yield a better fundamental understanding of potential aerobic and anaerobic transformation mechanisms for cis-DCE and VC. In addition, this research should lead to a better understanding of the site-specific factors that control these transformation processes in the subsurface environment and how to use them cost effectively for site-specific remediation approaches.

Detailed descriptions of the FY 2000 Cleanup Statements of Need may be found in Appendix E.

COMPLIANCE

Introduction

The DoD's Compliance goals are twofold-

- To ensure that all applicable environmental rules and regulations are met; and
- To eliminate or reduce the chances for Notices of Violation (NOV).

Within the United States, DoD must comply with Federal laws such as the Clean Water Act (CWA), the Clean Air Act (CAA), and the Resource Conservation and Recovery Act (RCRA), as well as state and local regulations. These laws result in requirements for the treatment and disposal of wastes generated during DoD operations by vehicles, aircrafts, and vessels, as well as the open burning and open detonation (OB/OD) of waste energetics. Requirements based on the 1990 CAA Amendments (CAAA) related to atmospheric emissions of hazardous air pollutants (HAP), volatile organic compounds (VOC), nitrogen oxides (NO_X), and particulate matter (PM) also are emerging.

At the international level, the International Maritime Organization's Marine Pollution Convention (MARPOL) Annexes (to which the United States subscribes) may restrict or prohibit DoD operations in international waters and MARPOL Special Areas unless vessels meet international environmental statutes. In addition, countries that host DoD facilities are implementing and enforcing compliance with regulations and standards that may restrict or prohibit DoD operations in foreign ports and bases.

Virtually all DoD activities and assets are subject to compliance with a wide range of environmental statutes and regulations that have impacts ranging from control of hazardous materials and effluents to treatment methodologies. Affected DoD activities and assets include training and operational installations; ordnance and weapons manufacturing; repair and rebuilding installations; and ship and aircraft operations. DoD is projected to spend between $2–3 billion annually for environmental compliance. New technologies must be developed to reduce this cost and enable the DoD to comply fully with increasingly stringent requirements so that it may fulfill its mission unencumbered by regulatory fines, restricted access, and negative public reactions.

The mission of the Compliance Technology Thrust Area is to conduct research and development to support waste treatment and disposal, environmental monitoring, marine risk assessment, and environmental management that is not directly related to site restoration but related to meeting current and future environmental compliance requirements of DoD and DOE. It also includes end-of-pipe recycling (i.e., waste that is reused for other than its original purpose). Further, it addresses understanding the fate and transport of defense-related air and wastewater discharges. It does not include elimination of waste streams through substitution or process modification. These are included in the Pollution Prevention Thrust Area.

Principal Driving Requirements

The primary concerns in this technology thrust area include loss of operational capability, the cost of regulatory compliance, and significant legal requirements. Each uniformed Service has submitted its User Requirements for Compliance, which are prioritized in the DoD Environmental Technology Requirements Strategy. These primary DoD environmental concerns reflect the need to:

- Better characterize DoD wastes and pollutant behavior;
- Control and monitor air emissions and wastewater/sludge discharges;
- Develop improved fate and transport prediction capabilities for discharges (including specific contaminants);
- Minimize and control shipboard and land-based sources of solid waste (including plastics);
- Develop effective treatments of hazardous waste; and
- Reduce emissions of hazardous air pollutants.

Compliance issues are addressed by the following three major subthrust areas related to affected environmental media and/or waste types: air, water (wastewater), and soil/sediment (solid waste and sludge). Beginning in FY 1998, the noise subthrust area of compliance was moved to the Conservation Thrust Area. These media are further categorized into specific types of pollutants, monitoring actions, or processes as illustrated in Figure III-4.

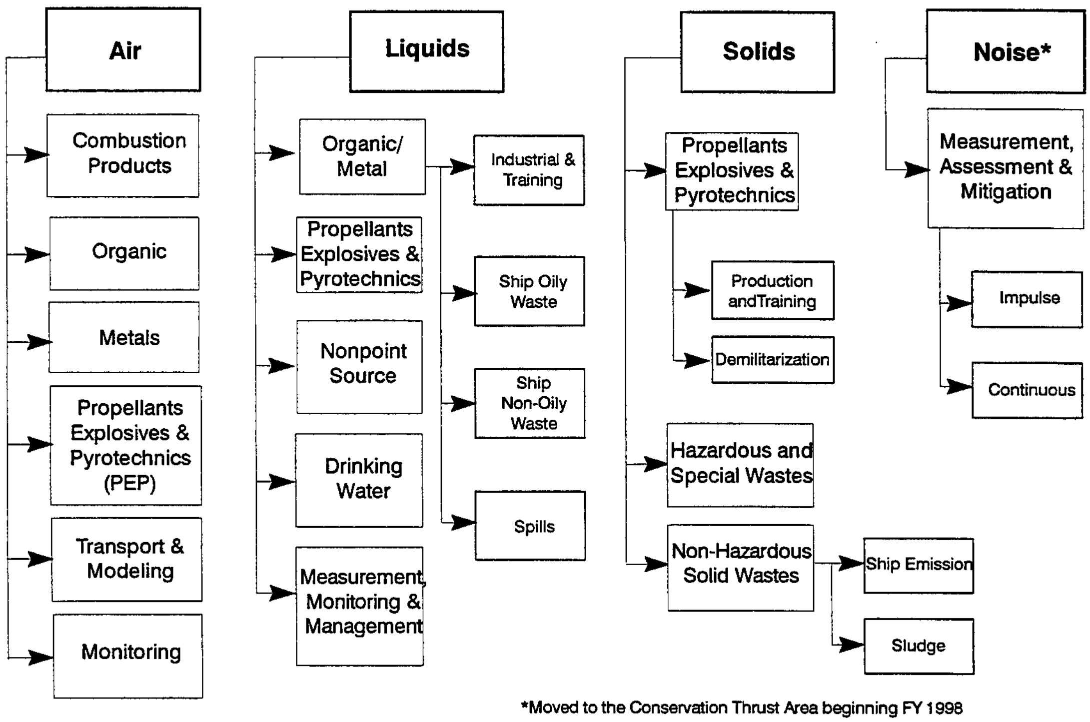

Figure III-4. Compliance Taxonomy

Military operations, training, and manufacturing activities can be restricted severely if they do not comply with existing environmental regulations. In the course of implementing the CAAA of 1990, a number of local air quality jurisdictions (many facing non-attainment status for one or more priority pollutants) have imposed local standards that are more stringent than the national emission standards. The employment of military-unique systems (e.g., liquid-fuel rockets, military jet engines, and mobility equipment) will require that DoD control emissions of NO_X and HAPs, including VOCs, at DoD installations. One difficulty associated with controlling and monitoring these emissions is that they frequently are episodic (e.g., jet engine test cells, painting, stripping and cleaning operations). Existing Clean Air Act regulations and anticipated future restrictions on NO_X/HAPs/VOCs are testing the limits of existing emissions control technology which in some cases does not meet portability or detection limit requirements. Without new technology, the curtailment of missions, closing of facilities, and assessment of fines are real possibilities.

The environmentally-safe disposal of the huge stockpile of munitions and propellants accumulated by all parties during the Cold War present a substantial challenge worldwide. More than 60 percent of these materials are not amenable to disposal by disassembly, recycling, or incineration. Therefore, disposal by OB/OD has been one of the only means applicable. OB/OD is a relatively simple and cost effective method for stockpile reduction, but it can generate excessive air pollutants. Concerns about the short- and long-term impacts of OB/OD activities on the health of humans and ecosystems have restricted severely and sometimes prohibited OB/OD in the U.S. and many other countries. FY98 was the last year that SERDP will initiate R&D in this area as a result of the establishment of the DoD Conventional Munitions Demilitarization Office.

Lead-based paint has been used on more than 1 billion square feet of DoD structures and buildings, including more than 200,000 DoD family housing units in the continental United States and 22,000 in Hawaii. Lead-based paint is a potential hazard to occupants, especially children below the age of six years. The cost of removal of lead-based paint from DoD structures and buildings is estimated to be more than $1 billion and presents a health hazard to remediation workers using current technology.

The Clean Water Act of 1977 prohibits the discharge of untreated sewage (blackwater) by ships in navigable waters. Shipboard graywater is the product of hotel and commissary-type activities aboard U.S. Navy ships. Common sources of graywater are showers, sinks, and galley and scullery equipment. No graywater holding capacity has been required for U.S. Navy ships with the exception of operations within the Great Lakes. However, with anticipated tightening of global wastewater discharge regulations and the designation of Global Special Area, the U.S. Navy needs to develop technologies that are appropriate for the control and treatment of combined shipboard graywater and blackwater (i.e., non-oily wastewater) as one of their environmental priorities. Further, DoD must meet international environmental regulations limiting the disposal of solid waste and plastics at sea. To address this need, the Navy must develop compact, efficient equipment for the destruction of solid waste onboard DoD vessels.

SERDP's Compliance Thrust area is currently funding projects within four technical approach categories:

- Monitoring and Measurement
- End-of-Pipe Reduction
- Treatment of Hazardous Wastes
- Systems Approach

Technical approaches, under the category of monitoring and measurement, focus on the identification, definition, fate and transport, and concentration (i.e., source term, exposure concentrations, release rates, etc.) of contaminants as they relate to specific compliance issues. Monitoring and measurement of contaminants are needed to comply with regulations pertaining to all waste types in all environmental media. End-of-pipe reduction approaches focus on minimizing the amount, toxicity, and type of pollutants resulting from a specific process. These approaches often have restrictions on modifications to the process that is producing the waste stream. Consequently, end-of-pipe reduction approaches tend to focus on short-term minimization of the hazardous elements of the waste stream with relatively minor changes to the process itself. Often, the types of compliance problems associated with end-of-pipe approaches have a parallel pollution prevention effort with a longer-term orientation to solving the same problem. A pollution prevention approach usually involves complete elimination of the waste stream as a result of a change in the process or product, whereas, an end-of-pipe approach involves an alternative process(es) that addresses the immediate requirements for compliance. Another important category of technical approaches is the treatment of hazardous wastes. The difference between the end-of-pipe reduction approach and a treatment approach is that the latter deals with elimination of hazardous constituents from discharged wastes prior to disposal.

Some compliance projects are focused on systems analysis which addresses more than one technical approach and environmental media (waste types). A systems approach is often used to develop assessment

tools for program managers who must set priorities, maintain safety, and plan compliance strategies for entire installations, as well as, communicate their compliance plan successfully to regulators and the public. Projects oriented toward systems analysis are considered under the systems approach category.

Compliance projects are fairly balanced between the three key technical approach areas - six projects under monitoring and measurement, six under end-of-pipe reduction, and 10 under treatment of hazardous waste. For FY98, SERDP supported a total of 21 Compliance projects. The majority of these projects address air emissions, reflecting the emphasis to respond to existing clean air regulations and the anticipated CAAA requirements for particulate matter less than 2.5 microns in diameter. FY 2000 New Starts will focus on monitoring and measurement of key pollutants in seawater, sediment, and soils to address water and solid media under the monitoring and measurement category.

Figure III-5 shows the funding by subthrust area. For FY 1998, Compliance received approximately 16 percent of the total SERDP budget. A slight decrease in SERDP's Compliance Technology Thrust Area investment is anticipated over the next five years, although this could change with the implementation of new environmental regulations. Congress appropriated funds in FY 1998 and FY 1999 specifically to conduct efforts in support of cleanup worker health and safety training aspects. This project is represented under the "Other" category in Figure III-5.

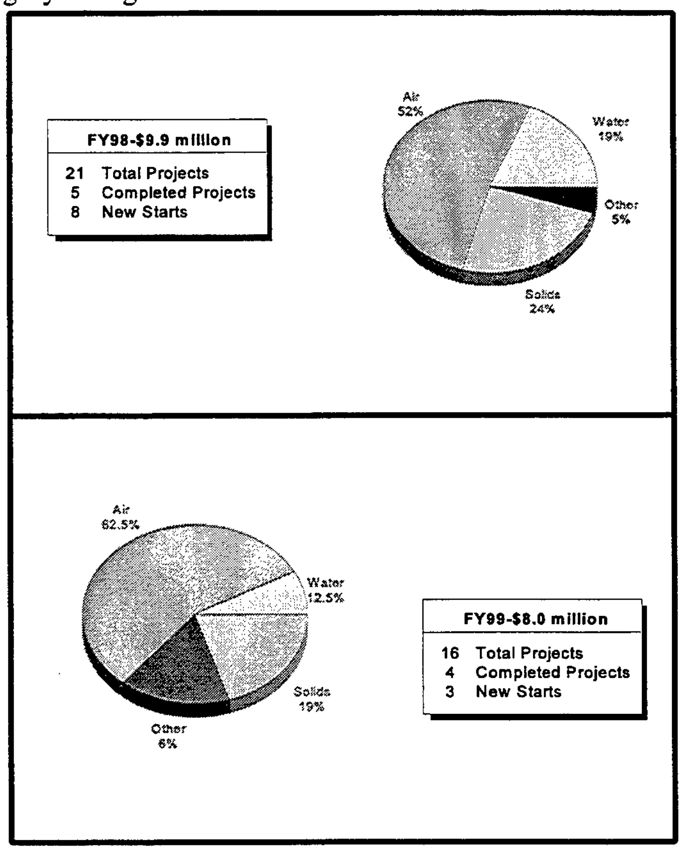

Figure III-5. SERDP Compliance Funding, FY 1998-FY 1999

Leveraging with other Defense science and technology programs and industry, the Compliance Technology Thrust Area focuses on the following research and development objectives:

- Develop control, treatment, and disposal technologies for ship operations (bilge, grey/black wastewater, solid waste, and air emissions);
- Develop new control, treatment, and disposal technologies for hazardous wastes resulting from manufacturing, maintenance and industrial operations, and installation support operations (wastewater, solid waste, and air emissions);
- Develop control and monitoring techniques for air toxic emissions to include development and testing of models to predict emissions of, and exposures to, pollutants from Defense facilities and to design effective, multimedia environmental management strategies;
- Develop improved monitoring, characterization, and assessment tools related to environmental compliance and management; and
- Develop standardized risk assessment methods, protocols, models, and data for air and wastewater discharges related to defense activities.

Compliance Program

The following list reflects FY 1998 completed projects and projects continuing into FY 1999. Also included are titles of projects that begin in FY 1999. Complete descriptions of all of the projects for FY 1998 and FY 1999 may be found on the pages referenced in Appendix B - Compliance Project Summaries.

Subthrust 1 - *Air*

Other

FY 1998 Continuing Projects

FY 2000 Compliance Initiatives

FY 2000 Compliance Initiatives reflect both the aim in proposed rules/standards and the need for programmatic balance across the technical approaches represented by the currently funded compliance projects. DoD's Proposed Range Rule and the Uniform National Discharge Standards were identified as important drivers for formulating FY 2000 Compliance Initiatives.

DoD's proposed Range Rule sets forth the process for addressing UXO, munition fragments, and other contaminants on ranges that are no longer needed to support the DoD mission, e.g., FUDS or Defense BRAC sites. Fundamental to DoD's efforts is a need for a better understanding of the sources, distribution, and environmental fate of energetics on DoD munitions test and training ranges. SERDP's initiative to identify the **Distribution and Environmental Fate of Energetics on DoD Munitions Test and Training Ranges** seeks to develop the techniques and knowledge to assess effectively the potential for environmental impacts of residual energetic material at test and training ranges.

The proposed rule for Phase I of Uniform National Discharge Standards (UNDS) describes discharges that are incidental to the normal operation of DoD's vessels and identifies which of these discharges DoD will be required to control. Integral to the further development of UNDS is the need to better understand the fate and impact of specific contaminants released from vessels such as copper and zinc from anti-fouling coatings on ship hulls. SERDP's initiative to identify the **Fate and Impact of Copper and Zinc in Harbors and Estuaries** is an effort to advance scientific knowledge of the fate and impact of copper and zinc from DoD sources in harbors and estuaries to develop a scientific basis for future approaches to copper and zinc regulations.

Detailed descriptions of the FY 2000 Compliance Statements of Need may be found in Appendix E.

CONSERVATION

Introduction

To continue to train and test military capabilities in a realistic and safe manner, DoD must maintain the nation's natural and cultural resources of the installations upon which it depends. It also must comply with legislation and regulations designed to protect these resources. DoD's challenge is to balance the use of air, land, and water resources for current military readiness with the need to protect and manage these resources for all desired long-term uses.

The Defense Department's Conservation goal is to support the military mission by (1) providing for sustained use of its land, sea, and air resources; (2) protecting valuable natural and cultural resources for future generations; (3) meeting all legal requirements; and (4) promoting compatible multiple uses of those resources. Knowledgeable, proactive management of natural resources and cultural resources is critical because the natural environment provides the realistic training environment in which to exercise and test the capabilities of the military forces. Several Federal statutes such as the Endangered Species Act (ESA); the National Environmental Policy Act (NEPA); the Sikes Act; the Migratory Bird Treaty Act; the Fish and Wildlife Coordination Act; the Marine Mammal Protection Act (MMPA); the National Historical Preservation Act (NHPA); the Historical and Archaeological Data Preservation Act; the Native American Grave Protection and Repatriation Act (NAGPRA); the American Indian Religious Freedom Act; the Flood Disaster Protection Act; and local laws, regulations, and requirements provide specific stewardship direction for all DoD and DOE lands. Other Conservation requirements include The American Heritage Rivers Initiative and four Conservation Presidential Memorandums involving Recreational Fisheries, Indian Sacred Sites, Floodplain Management, and Protection of Wetlands, which further implement and support the above mentioned Federal statutes.

DoD and DOE must be effective and proactive stewards of natural and cultural resources under their direction. By better understanding the environments in which they operate, the Departments can improve their resource-use decisions to promote conservation and stewardship, while continuing to fulfill their primary missions. DoD's conservation concerns as depicted in Figure III-6 can be divided into three distinct operating areas in which the Department conducts training and testing and, therefore, impacts the natural environment: air, land, and water (oceans and waterways).

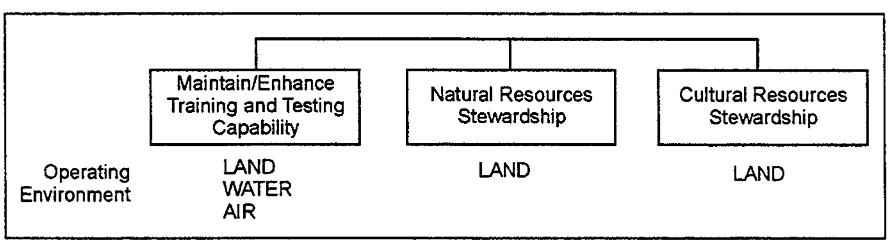

Figure III-6. Conservation Taxonomy

Figure III-7 shows the funding by subthrust area. For FY 1998, Conservation received approximately 14 percent of the SERDP budget. In FY 1998 and beyond, Conservation funding gradually will grow to support a more sustainable future.

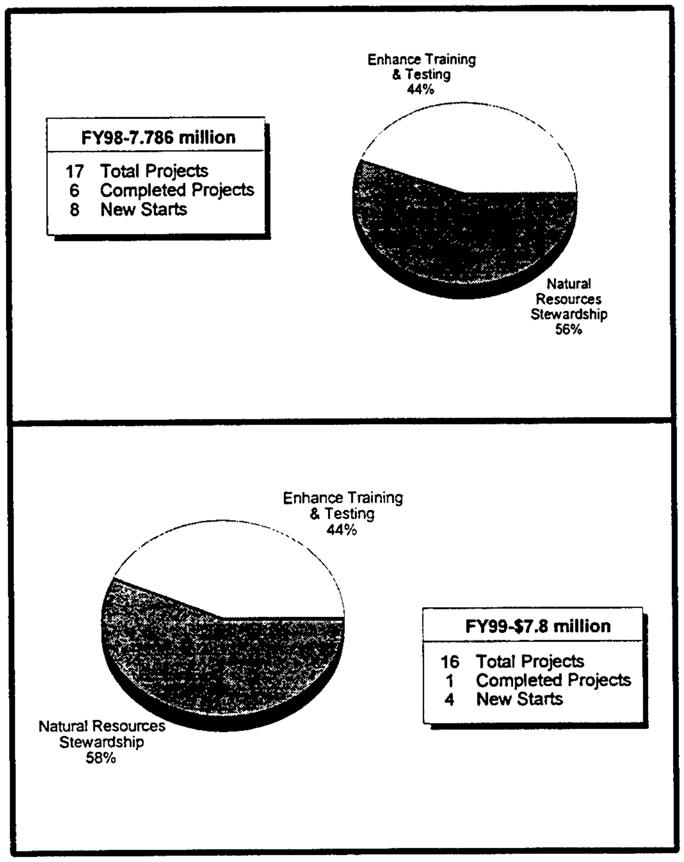

Figure III-7. SERDP Conservation Funding, FY 1998-FY 1999

Principal Driving Requirements

Each uniformed Service has submitted its User Requirements for Conservation, which are prioritized in the DoD Environmental Technology Requirements Strategy. These individual requirements affect all operating environments and can be grouped into three related but distinct principle driving requirements, which are the needs for DoD:

- To maintain and enhance its training and testing capability to ensure military readiness;
- To steward and protect the natural resources under its control; and
- To steward and protect the cultural resources under its control.

The Department of Defense is a major user of land, sea, and air, managing 25 million acres of land on more than 425 major military installations, and it is the third largest Federal land management department in the United States. DoD requires continued access to these lands to maintain mission readiness. Land is needed for munitions testing, deployment of weapon systems, and combat training exercises. Marine and estuarine environments are needed to conduct training exercises, test vessels and submarine tracking equipment, evaluate missile weapon systems, and conduct shock trials on new ships. Airspace is needed to train pilots and test fighter planes and air-based weapon systems. The specific landscapes and unique natural features of the land, sea, and air space used by DoD are crucial to military readiness. Varied training regimens and differing climatic, topographic, hydrologic, and biological settings prepare troops to operate equipment and carry out operational plans under conditions they may encounter in future conflicts. With a broad geographic distribution (largely domestic but some foreign), DoD lands represent a remarkably diverse collection of ecosystem and habitat types, including forests, grasslands, wetlands, and deserts. DoD's ability to conduct realistic training exercises and to test weapon systems and equipment cannot be ensured without responsible stewardship and sensible management and conservation practices. Currently, one half of the Army's training ranges are under some level of environmental restriction.

In the Air Operating Environment, the Air Force is required to assess the impacts of proposed aircraft operations on the environment. Many of the assessments accomplished to date contain unsubstantiated, anecdotal remarks concerning the effects of aircraft noise on wildlife. Quantitative data are needed for environmental planners at the major command and Air Staff levels to defend the Air Force's low altitude Military Training Routes (MTR), which are essential for combat training. The U.S. Fish and Wildlife Service can and has stopped proposed low altitude flight activities through the use of formal Section 7 consultations in accordance with the Endangered Species Act.

In the Water Operating Environment, the Navy must comply with the National Environmental Policy Act (NEPA), the Endangered Species Act (ESA), and the Marine Mammal Protection Act (MMPA) in all operations and tests. This is a difficult task when "take" is defined under the MMPA to mean "harass, hunt, capture, or kill, or attempt to harass, hunt, capture, or kill any marine mammal."

The Departments of Defense and Energy lands are subjected to a wide variety of uses ranging from military training to hazardous waste disposal to timber production. Nevertheless, these lands are often the last large natural areas in otherwise developed environments. As such, they represent valuable resources for preserving the biodiversity of their local regions, and they serve as refuges for a wide variety of threatened and endangered species. Nearly 1,000 species in the U.S. are protected under the Endangered Species Act (ESA), while thousands more are candidates for listing. More than 200 installations provide habitat for at least 400 plants and animals that are listed on or candidates for the Federal endangered species list. This is the highest known density of threatened and endangered species found on any Federal lands. DoD Installations contain some of the finest remaining examples of such rare native vegetative communities as old-growth forests, tall-grass prairies, and vernal pool wetlands. This can lead to mission constraints and impediments to land acquisition, potentially leading to reduced defense readiness; lengthy and costly litigation; and sometimes criminal and civil penalties. DoD's ability to address this issue is limited because of inadequate information on distribution and abundance of threatened and endangered

species (TES) and their habitats on military land, the effects of mission activities on TES and supporting ecosystems, and appropriate mitigation and management options.

Furthermore, military facilities face increasing demands as a result of base closures and realignments, new weapon systems and equipment requiring larger training ranges, additional regulatory constraints, and changes in tactics and doctrine. Training intensity on remaining installations will continue to rise, often preventing full recovery of vegetation between training exercises. The U.S. Army alone has 11 million acres of training and testing lands with land repair and maintenance costs of $56 million annually. On-site and off-site environmental impacts, wildlife conservation issues, cultural resources concerns, and the need for training realism all dictate that natural resources must be maintained and enhanced on these installations. The tasks of balancing military land uses, complying with resource regulations, and assessing impacts on the sustainability of both the resource base and the military mission are complex and challenging. Activities to alleviate one problem can often exacerbate others. All too often, decision-makers on military installations are faced with making critical land management decisions without the benefit of complete environmental information nor complete knowledge of other, competing objectives and/or land use requirements.

The current reliability associated with the detection and location of cultural and archeological artifacts is minimal. Once a cultural or archeological resource site is identified, it must then be assessed in order to determine its significance. Currently, the costs associated with Phase II assessments of cultural and archeological resources are quite high. In the Army alone, there are approximately 100,000 archeological sites, and at least 200 installations have properties that are listed on or eligible for the National Register of Historic Places. In addition, DoD must comply with the requirements of NAGPRA, which protects Native American artifacts and cultural items, and the Archeological and Historic Preservation Act, which requires evaluation of proposed activities on the cultural environment. New techniques and capabilities are needed to reduce the costs of compliance and to avoid delays and the possibility of damaging artifacts when an unanticipated but significant discovery occurs at a construction site.

Leveraging with other Defense Science and Technology programs and industry, SERDP focuses on the following Conservation research and development objectives:

- Develop standardized, cost effective methods to inventory, characterize, and monitor natural and cultural resources to help ensure compliance with applicable laws and requirements. Where appropriate, use defense-unique data collection and assessment tools to develop these methods;

- Develop and demonstrate more effective methods and techniques to maximize availability of military lands in support of military missions, with minimal impact to natural and cultural resources in a manner consistent with the Services' mission and Federal environmental regulations;

- Develop and demonstrate efficient and effective techniques to conserve and restore natural and cultural resources proactively, particularly threatened and endangered species and the ecosystems on which they depend;

- Develop and demonstrate effective, user-friendly computer-based models to determine the incremental and cumulative impact of military activities on natural and cultural resources, and assess effectiveness of conservation and restoration techniques;

- Develop state-of-the-art techniques to assess and predict the impact of military use on those critical elements of the ecosystem impacting biodiversity; and

- Develop the needed methods, tools, guidelines, and decision support systems for effectively implementing integrated resource management techniques.

Conservation Program

The following list reflects FY 1998 completed projects and projects continuing into FY 1999. Also included are titles of projects commencing in FY 1999. Complete descriptions of all of the projects for FY 1998 and FY 1999 may be found on the pages referenced in Appendix C - Conservation Project Summaries.

Subthrust 1 - *Maintain/Enhance Training/Testing Capability*

FY 1999 New Start Projects

Subthrust 2 - *Natural Resources Stewardship*

FY 1998 Completed Projects

FY 1999 Continuing Projects

FY 1999 New Start Projects

None

Subthrust 3 - *Cultural Resources Stewardship*

FY 1998 Completed Projects

None

FY 1999 Continuing Projects

None

FY 1999 New Start Projects

None

FY 2000 Conservation Initiatives

There is one FY 2000 proposed new initiative in Conservation's Maintain/Enhance Training and Testing subthrust area and one new initiative planned in the Natural Resource Stewardship subthrust area. In the Training and Testing subthrust area, SERDP plans a new effort in the area of **Riparian Zone Rehabilitation to Restore Terrestrial and Aquatic Ecosystem Functions**. The focus of this initiative is on technologies designed for the dual purpose of sustaining of military lands and mitigating aquatic and terrestrial ecological impacts associated with military land use activities. Efforts will address some or all of the following objectives:

1. Determine the impacts of military activities upon aquatic ecosystems and water quality.

2. Determine which benefits may be derived from riparian zone and stream corridor rehabilitation and management programs on military lands as they affect aquatic ecosystem structure and function.

3. Determine if riparian zones and stream corridors can be managed intensively to achieve multiple ecosystem protection and restoration goals.

4. Identify the principal physical, chemical, and ecological requirements (in a management and technology sense) that need to be addressed to manage riparian zones and stream corridors such that the functions of both terrestrial and aquatic ecosystems are sustained. These requirements may include, but are not limited to: controlling biogeochemical cycling; building habitat features; and understanding plant dynamics, geomorphology, hydrology and sediment transport.

Natural Resources Management Control of Non-Indigenous Invasive Species develops new or improves existing methods for the early identification, monitoring, and management/control that would lead to reduction and possible elimination of non-indigenous invasive plant and animal species on DoD installations. The focus of this research initiative is targeted toward methods that specifically address issues relative to the ecological and mission sustainment requirements of DoD lands. Efforts will address the following objectives:

1. Develop methods to inventory the spatial extent and, where applicable, the densities of established populations of non-indigenous species on military bases. Methods should be applicable for use across a large region of military bases.

2. Develop methods to estimate the likelihood of non-indigenous species expansion into and/or invasion of, new habitats/areas on military bases.

3. Improve existing and/or develop new and more effective management/control technologies against established and expanding populations of non-native introduced species while effectively protecting native species and their habitats.

The Management-Scale Ecosystem Initiative is critical for obtaining scientific information to support an ecosystems management approach at DoD installations, especially with respect to mission concerns. The success of ecosystems management plans will depend on the capabilities and increased knowledge generated by research investment. In FY 2000, the SERDP Ecosystem Management Program (SEMP) will focus on the **Ecological Disturbance in the Context of Military Landscapes** initiative to develop the knowledge required to implement adaptive ecosystem management approaches for military lands and waters, as well as other Federal facility lands and waters. Efforts under this SERDP initiative will address of the following objectives:

1. Identify the historical range of variation in types, spatial extent, intensities, and frequencies of natural disturbances across the landscape associated with specific ecological and/or land use conditions.

2. Describe how current DoD activities within the ecosystem compare to past disturbance regimes, in terms of affecting specific ecological and/or land use conditions.

3. Determine whether there are thresholds in spatial extent, intensity, or frequency above and/or below which the natural system cannot sustain identified ecological and/or land use disturbances.

Detailed descriptions of the FY 2000 Conservation Statements of Need may be found in Appendix E.

POLLUTION PREVENTION

Introduction

The Pollution Prevention Technology Thrust Area focuses on reducing or eliminating the generation of pollution within the DoD. The application of pollution prevention technologies will influence positively the other DoD environmental Thrust Areas by encouraging the use of innovative technologies and practices such as recycle, recovery and reuse, reducing pollutants to be managed at the source, and promoting the sustainable use of natural resources.

As defined under the Pollution Prevention Act of 1990, pollution prevention means "source reduction" and other practices that reduce or eliminate the creation of pollutants through increased efficiency in the use of raw materials. Source reduction is defined as any practice that reduces the amount of any hazardous substance, pollutant, or contaminant entering any waste stream or otherwise released into the environment (including fugitive emissions) prior to recycling, treatment, or disposal. SERDP Pollution Prevention does address end-of-pipe recycling of wastes for originally designed uses, such as the recycling of munitions and their materials back into the production of new munitions.

The DoD and DOE have a number of unique functions, such as the development and operation of sophisticated weapons systems which demand specialized, high-performance materials. Many of these materials are toxic and are targeted for voluntary reduction. The challenge to DoD and DOE is to find new

high-performance materials that are not toxic and/or to determine innovative ways to control the use of toxic chemicals in order to reduce releases and off-site transfers.

Waste minimization programs in the commercial sector have demonstrated that pollution prevention saves money. Addressing pollution prevention for technologies not adequately addressed by the private sector will be the focus for DoD and DOE to meet their environmental obligations in a cost effective manner. Material substitutions, manufacturing process changes, inventory and stockpile controls, and adjustments to routine, daily processes will be required to meet these obligations.

The Pollution Prevention Thrust Area, at the recommendation of the SERDP Scientific Advisory Board, is adopting a proactive approach to provide solutions to the highest priority defense related environmental problems. The Pollution Prevention Thrust Area, in addition to addressing near term multi-service DoD problems, also will address more forward looking, high-risk, long-term projects to achieve the goals that will be set forth by future regulations. For example, the development of the next generation of environmentally advantaged DoD systems is key to meeting potential future regulations. This will be done by designing tools to alert planners to potential environmental issues. SERDP will work closely with military planners service research organizations and the Office of Deputy Under Secretary of Defense for Environmental Security to identify long-term needs for the Department.

The Pollution Prevention TTAWG recommended a change in program emphasis within the pollution prevention pillar. They believed that the role of the Services should be to identify and address the compliance issues within their respective services and that SERDP should focus its resources on addressing the more global, tri-Service issues and on developing seed technologies to address emerging regulatory issues. SERDP also should facilitate communication and collaboration to enhance technology transfer and to leverage Service and SERDP resources. This will be accomplished through increased interaction with the National Defense Center for Environmental Excellence (NDCEE) and, the National Center for Manufacturing Science (NCMS) and participation in Joint Acquisition Sustainment Pollution Prevention (JASPA) initiatives. As a first step in fostering technology transfer to DoD depots, the JASPA chairman has been invited to participate on the TTAWG.

SERDP is using workshops in specific technology areas to understand better the existing state-of-the-art in these areas and to identify environmentally driven requirements and any industry or DoD initiatives addressing them. In addition to fostering technology transfer, this information is used to help focus the SERDP program on the highest priority issues and to avoid duplication of effort. A joint Pollution Prevention/Compliance workshop on air and particulate emissions is planned for June 1999.

The Air Force, Army, and Navy have each submitted their Pollution Prevention User Requirements, which are prioritized in the DoD Environmental Technology Requirements Strategy. These requirements can be grouped into specific environmental concerns. The primary DoD environmental concerns in Pollution Prevention are the need to:

- Identify alternatives for hazardous and toxic chemicals/materials;
- Reduce the use of hazardous and toxic chemicals/materials;
- Reduce the volume and toxicity of wastes and pollutants through source reduction;
- Improve the efficiencies of mechanical and chemical systems;
- Incorporate environmental ramifications as key evaluation considerations in major system design and acquisition; and
- Consider the life-cycle effects of materials and systems.

These DoD Pollution Prevention needs are addressed by the four major subthrust areas of Air, Water, Solids, and Modeling and Measurements, which are further organized as shown in Figure III-8.

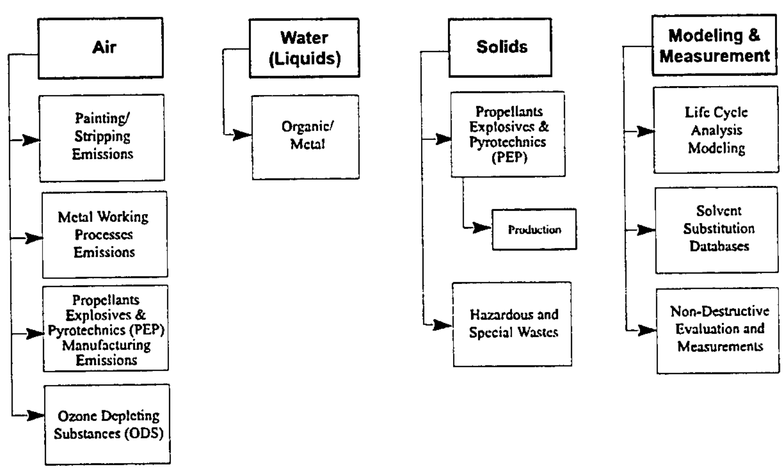

Figure III-8. Pollution Prevention Taxonomy

Future SERDP Pollution Prevention projects will be selected based on the following general metrics:

- Expected payoff (i.e., potential cost avoidance);
- Magnitude of the environmental problem that the technology will address;
- Potential environmental benefits and impacts on the defense establishment should be clear, regardless of whether it addresses current, near-, mid-, or long-term needs; and

- Leveraged funding from Services/Agencies is highly encouraged.

The FY 1998 and FY 1999 distribution of SERDP funding for Pollution Prevention among the subthrust areas is shown in Figure III-9. For FY 1998, Pollution Prevention received approximately 31 percent of the SERDP budget. In the out years, Pollution Prevention will continue to grow relative to the three other technology areas of SERDP in order to meet DoD users' demands for better, cheaper, and cleaner weapons systems and processes.

Principal Driving Requirements

Executive Order 12856, "Federal Compliance with Right-to-Know Laws and Pollution Prevention Requirements," states that the Federal Government should become the leader in the field of Pollution Prevention through the management of its facilities, its acquisition practices, and supporting the development of innovative pollution prevention programs and technologies. The Executive Order challenges the heads of the Departments of Defense and Energy to set goals voluntarily to reduce their agency's total releases of toxic chemicals to the environment and off-site transfers by 50 percent from 1994 baseline figures by December 31, 1999.

Virtually all DoD maintenance and repair activities involve the use of toxic or hazardous substances. The 1990 CAAA, the Resource Conservation and Recovery Act (RCRA), and state and local regulations restrict the emission and disposal of these hazardous materials. Ozone depleting substances (ODS) are being phased out of production under national policy and international (Montreal) protocol. DoD directives require significant reductions in hazardous wastes and development of alternative materials and processes that meet environmental restrictions and allow DoD to continue operations. Operations and training activities at DoD installations and facilities generate large quantities of hazardous, non-hazardous, and special wastes that are expensive to manage and dispose.

During this decade, an increasing emphasis has been placed on pollution prevention to reduce environmental impacts associated with DoD weapon systems acquisition. The DoD Pollution Prevention Strategy of August 11, 1994, established a goal to identify and develop environmental life cycle cost estimating tools that inject pollution prevention and other environmental concerns into acquisition decisions. Development and application of modeling and simulation tools to identify and test technical solutions that reduce reliance on toxic materials and processes are required.

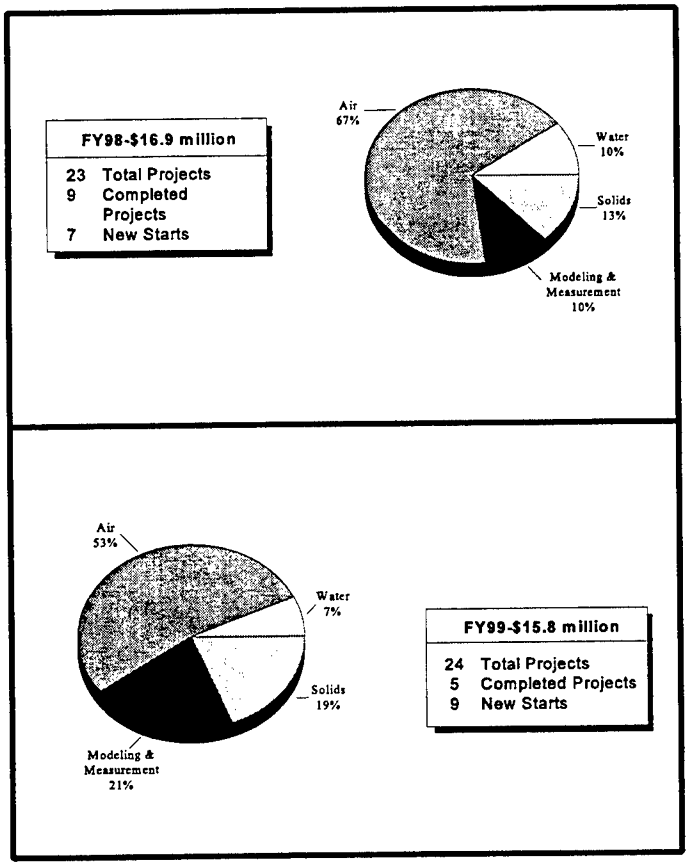

Figure III-9. SERDP Pollution Prevention Funding, FY 1998-FY 1999

Leveraging with other DoD, DOE, and EPA science and technology programs and industry, the Pollution Prevention subthrust areas focus on the following research and development objectives:

- Alternative materials and processes to replace defense uses of hazardous heavy metals (e.g., chromium, cadmium, lead, nickel) and metallic compounds and hazardous air pollutants;
- Alternatives to VOC containing coatings, adhesives, sealants, and lubricants that are not being addressed adequately by industry;

- Alternatives to hazardous and toxic chemicals for surface cleaning, degreasing, and paint stripping;
- Alternatives to hazardous and toxic chemicals, especially ODS, used in climate control, refrigeration, as solvents, and as fire-fighting agents;
- Techniques to regenerate, recycle, re-use, and stockpile defense unique toxic chemicals and materials;
- On-line sensors and monitoring systems to prolong usefulness of toxic chemicals in defense operations such as plating, stripping, and mechanical maintenance;
- Cost-effective, environmentally preferable packaging and recycling approaches to reduce generation of solid waste from defense-related operations; and
- Predictive models (which include environmental life cycle costing) to aid in the development of environmentally sound weapon systems and platforms during concept development, design, test and evaluation, maintenance (logistics support documentation), and decommissioning.

Pollution Prevention Program

The following list reflects FY 1998 completed projects and projects continuing into FY 1999. Also included are titles of projects commencing in FY 1999. Complete descriptions of all of the projects for FY 1998 and FY 1999 may be found on the pages referenced in Appendix D - Pollution Prevention Project Summaries.

Subthrust 1 - *Air*

Subthrust 4 - *Modeling & Databases*

FY 2000 Pollution Prevention Initiatives

SERDP is proposing two new start initiatives, both in the Air subthrust area. The first initiative is to find alternatives to hard chrome elctroplating. Metallic chromium is the preferred surface material for many applications where wear resistance, corrosion resistance, dimensional consistency, and/or smoothness are required on substrates chosen for other key material properties. By far, the most common method of applying chromium is via wet immersion electroplating. Electroplating of chromium, as currently practiced, involves the use of heated, agitated, corrosive solutions of a heavy metal in its water-soluble form. A number of add-on devices and treatment processes are used to keep this inherently dirty, polluting, and unsafe operation in compliance with ever tightening environmental and worker safety regulations. The Army, Navy, and Air Force have been conducting research at the demonstration/validation stage on a High Velocity Oxy-Fuel (HVOF) spraying process that is limited to direct line-of-sight application. Other processes are limited by film build-up and are too slow for typical surface areas. Consequently, there is no universal solution to eliminate hard chrome electroplating.

The objective of this first SERDP new start initiative **Alternative to Hard Chrome Electroplating Technology** is to develop environmentally friendly replacement technology for current wet hard chrome electroplating for defense applications. Alternatives to hard chrome electroplating technology will focus on non-line-of-sight applications and other applications where current High Velocity Oxy-Fuel (HVOF) technology cannot be used to replace electroplating. Such configurations include angles, crevices, and the insides of holes or tubular shapes. Innovative application techniques and alternative materials will be considered.

The second SERDP new start initiative **Environmentally Innovative Technologies for Specialty Coatings Applications/Removal and Repair** intends to develop environmentally benign application, removal, and repair processes for specialty coatings that meet unique requirements of DoD weapon systems. These specialty coatings contribute greatly to the DoD mission and often are enabling technologies. Very little work has been done to improve specialty coatings application and removal processes because they have been exempted from regulation and are not presently limited to a set amount of VOCs and/or HAPs per unit volume. However, their contribution to atmospheric releases is significant. The focus of this initiative will be on any of the following special use coatings: rain and dust erosion control on aircraft leading edges and radomes; fuel tank corrosion control; air/sea/ground-based antennae and support structures signature reduction; thermal barriers; composites; and radar absorbing materials for all applicable weapon systems are within the scope of this effort. Systems approaches and the potential for lower life cycle environmental impact than current specialty coatings processes will be emphasized. The development of new application, repair, and/or removal processes for speciality coatings will result in significant reductions in the production and/or release of VOCs, HAPs, and hazardous materials and waste streams associated with these coatings and will reduce life cycle costs.

APPENDIX A
Cleanup Project Summaries

PROJECT SUMMARY

PROJECT TITLE & ID: Mobile Underwater Debris Survey System (MUDSS); CU-52

RESEARCH CATEGORY: 6.3 Advanced Development

LEAD AGENCY: U.S. Navy

LAB: Naval Surface Warfare Center - Panama City, FL

PRINCIPAL INVESTIGATOR: Mr. John McCormick

FY 1998 COMPLETED PROJECT

OBJECTIVE: The goal of the MUDSS project is to demonstrate the multi-sensor technologies necessary for underwater surveys of shallow water, both inland and coastal sites littered with unexploded ordnance (UXO). This multi-sensor platform utilizes the following instruments: high- resolution, synthetic aperture sonar; highly-sensitive, superconducting, magnetic gradiometer; electro-optical sensor; chemical sensor; and laser line scanner. A successful demonstration will prove the system concepts for finding and mapping the locations of UXO targets ranging from small shells to large bombs in water depths between four and 100 feet. These technologies can then be applied to the environmental cleanup of underwater UXO targets at scores of formerly used defense sites (FUDS).

BENEFIT: The exact extent and amount of ordnance at most underwater FUD sites is unknown. MUDSS will provide a capability to survey these sites to determine the extent of the problem and to locate targets for remediation. Each MUDSS sensor will out-perform any commercial off- the-shelf (COTS) sensor, and the integrated MUDSS system will provide performance against UXO targets (including buried ordnance) far exceeding any COTS system. The development cost of this system has been minimized by using hardware and software components from parallel Navy and National Aeronautics & Space Administration (NASA) programs.

ACCOMPLISHMENTS: In FY98, hardware and software modifications were made to the original MUDDS data collection design to support system design changes. The original MUDSS data collection was to be on the towing platform. MUDSS is now taking advantage of the improvements of the Office of Naval Research (ONR) sponsored Advanced Concept Technology Demonstration (ACTD) where the data are transmitted to a remote operating station.

As part of the final year of SERDP funding, researchers planned to complete integration of sensors and perform field tests. The unfortunate Swissair Flight 111 mishap in 1998 offered researchers the opportunity to determine the capabilities of MUDSS in a real-world operational setting. MUDSS allowed the search team to quickly and accurately define the debris field in Peggy's Cove, off the coast of Nova Scotia. The MUDSS-based technology was tested under real-world conditions while performing a valuable service to the Canadian search team. Advanced systems such as MUDSS can even outperform human

divers, which the Canadians have used extensively in "Operation Persistence" in Peggy's Cove. MUDSS capabilities were tested recently against a team of divers on a North Sea oil platform. MUDSS was able to "see" and identify objects at a distance of 110 feet, while divers needed to be within 35 feet.

TRANSITION: MUDSS is a technology demonstration and transfer program. The research has married developing mine-hunting technologies from the Coastal Systems Station (CSS) with data fusion and visualization technologies developed for NASA by the Jet Propulsion Lab (JPL). Included are plans for an assessment of chemical sensor technology developed by JPL for the Federal Aviation Administration (FAA). The U.S. Army Corp of Engineers (USACE), which has the current mission for munitions remediation and cleanup for over 900 FUD sites, strongly endorsed the transition of MUDSS to an operational capability.

PROJECT SUMMARY

PROJECT TITLE & ID: Permeable Reactive Barriers for In-Situ Treatment of Chlorinated Solvents; CU-107

RESEARCH CATEGORY: 6.3 Advanced Development

LEAD AGENCY: U.S. Air Force

LAB: Air Force Research Laboratory - Tyndall Air Force Base, FL

PRINCIPAL INVESTIGATOR: Capt. Gus Fadel

FY 1998 COMPLETED PROJECT

OBJECTIVE: Pump-and-treat technology contains contaminant plumes and removes dissolved-phase contamination in relatively homogeneous geologic formations. As a result of the slight solubility of the contaminant into the surrounding groundwater, and sorption to aquifer materials during transport, pump-and-treat processes require the treatment of massive amounts of water to remove relatively little contamination. Estimates of the duration of pump-and-treat necessary to fully remediate contaminated sites range from decades to centuries. In consequence, the cost of pump-and-treat treatment is extremely high. A newly-developed process, called the funnel-and-gate, is an in-situ technique that directs contaminated groundwater under passive flow through an engineered subsurface region for decontamination.

The main objective of this project is the testing of alternative media at a field-scale, proof-of-principle demonstration. Two or three reactive media will be field-tested to compare their dechlorination potential. Another objective is to concurrently develop a field-tested permeable barrier design protocol for in-situ remediation of chlorinated solvents in groundwater that would be acceptable to state and Federal regulators.

BENEFIT: Many contaminated sites currently undergoing pump-and-treat remediation are expected to be tractable to funnel-and-gate configurations. With no active pumping required, these systems may be installed at sites for which power utility installation is a formidable obstacle to installation of pump-and-treat systems. The design protocol will be a tool available for Department of Defense (DoD) restoration project managers to use for designing barriers for other installations/hydrogeologic conditions. The design protocol document will also facilitate regulatory acceptance of this technology.

ACCOMPLISHMENTS: A site was selected at Dover Air Force Base (AFB) to perform a field demonstration in FY 97, which will investigate several reactive media components and innovative emplacement methods for the permeable wall to optimize hydraulic capture and treatment of the plume. In FY98, construction of the pilot-scale, permeable reactive barrier at Dover AFB was completed during early January. Water level and groundwater velocity measurements taken during February indicated groundwater flow through the gates. The construction subcontractor provided built drawings, well logs,

and sheet piling quality control records. Copies were provided to Dover AFB. The Environmental Protection Agency (EPA) and the National Exposure Research Laboratory (NERL) set up a new field column study at the site to investigate and predict precipitation and biofouling within the pretreatment and reactive zones of the barrier. Water level measurements were taken manually until mid-May. Water level maps indicating flow through the permeable reactive barrier were prepared. Groundwater velocity measurements continued using the in-situ, Sandia probes. The project team is working to increase the resolution of the probe data for the difficult, low-velocity, groundwater regime on site. Preparations for the July performance monitoring event was started. Sampling sequences, material requirements, subcontractor laboratory support, and site access was also coordinated.

TRANSITION: This project will provide a field-tested design guidance as a tool for DoD restoration project managers to use for designing barriers for other installations/hydrogeologic conditions. The project researchers presently serve as reviewers for actual and proposed funnel-and-gate pilot demonstrations at a number of sites, including: the Environmental Security Technology Certification Program (ESTCP) pilot investigation at Moffett Field, CA; the EPA full-scale demonstration planned for 1998, the Massachusetts Military Reservation (Otis AFB); and other sites. Future plans include working with Navy design teams and the Army Corps of Engineers to apply the technology as widely as possible.

PROJECT SUMMARY

PROJECT TITLE & ID: Aquifer Restoration by Enhanced Source Removal; CU-368

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Environmental Protection Agency

LAB: National Risk Management Research Lab - Ada, OK

PRINCIPAL INVESTIGATOR: Dr. Carl Enfield

FY 1999 FUNDS: $1,393K

OBJECTIVE: Low-solubility organics such as chlorinated solvents were used and released to the environment in massive quantities during the 1950s, '60s, and '70s. These contaminants have migrated through the subsurface and entered groundwater at more than 1,000 Department of Defense (DoD) sites. At these sites, the organic contaminants are found in one of four phases: (1) volatilized within the soil's vadose zone (vapor phase), (2) dissolved in the groundwater (dissolved phase), (3) sorbed to the aquifer solids (sorbed phase), or (4) as a separate non-aqueous phase liquid (NAPL) phase. All of these phases contribute to groundwater contamination and need to be removed.

The limiting factor to satisfactory remediation at over 75 percent of the hazardous waste sites in the United States is the restoration of groundwater quality. The major limitations of the successful use of pump-and-treat technology are related to difficulties in extracting contaminants from source areas where NAPLs exist. The objective of this research is to evaluate extraction processes (solubilization and mobilization), which have been developed at the bench scale, for their potential to enhance extraction in the source area. Design manuals are to be developed and evaluated using field pilot-scale cells for side-by-side comparison of technologies.

BENEFIT: It is estimated that over 90 percent of the contaminants in the subsurface environment are contained in the source area. Until the source area is remediated or contained, it will not be possible to obtain permanent closure for any of the sites. Pump-and-treat systems are the primary technology in use at sites with contaminated groundwater. Because of their inability to effectively clean contaminant sources, many of them will be operated "in perpetuity." The cost of operating and maintaining these systems is enormous, and the institutional arrangements to keep them operating for tens to hundreds of years do not exist. Bench-scale studies suggest that it will be possible to remove the majority of the NAPL where the source can be identified. The time required for this removal is small compared to the time required if pump-and-treat technologies are used. Estimated costs for groundwater remediation by DoD and other Federal agencies range into the hundreds of billions of dollars, and even incremental improvements in efficiency will justify the cost of the proposed research.

TECHNICAL APPROACH AND RISKS: The proposed work will be a series of field demonstrations of enhanced pump-and-treat technologies supported by site characterization and laboratory research required to produce credible field demonstrations and evaluations. The work will focus on remediation of source areas of sites believed to be contaminated by NAPLs at residual concentration (no longer mobile and, therefore, not available for extraction by pumping).

The processes will be demonstrated at different sites with a variety of hydrogeologic characteristics and chemical mixtures (both NAPLs and sorbed contaminants will be considered) to determine their performance under a variety of conditions. The tests will be conducted as controlled, small-scale field projects. Each technology will be compared to one or more alternative remediation technologies including conventional pump-and-treat as a reference treatment system. The results of these comparisons will show the differential improvement achieved by one process relative to another. Success of the project will be dependent on: the ability to obtain access to actual sites; obtaining regulatory permission to perform non-standard, pilot-scale evaluations without significant delay; and maintaining continuity of funding throughout the project.

ACCOMPLISHMENTS: In FY98, two test cells were installed and instrumented at the Groundwater Remediation Field Laboratory, Dover AFB. The first dense non-aqueous phase liquid (DNAPL) remediation demonstration has taken place. Tetrachloroethene was released into the test cell in June 1998 and tests have been conducted to delineate the DNAPL distribution within the cell. The co-solvent solubilization test began in October, 1998. Initial hydrodynamic characterization of the second test cell began in September in preparation for a surfactant solubilization demonstration.

TRANSITION: The results of these comparisons between alternative remediation technologies will be compiled into a manual. This manual will be prepared for the user community to facilitate design of these systems. The design manual will contain anticipated system performance and will be made widely available to facilitate transition of the technology developed.

PROJECT SUMMARY

PROJECT TITLE & ID: National Environmental Technology Test Sites (NETTS) Program — Consortium for Site Characterization Technology; CU-374

RESEARCH CATEGORY: 6.4 Demonstration and Validation

LEAD AGENCY: U.S. Environmental Protection Agency

LAB: National Exposure Research Laboratory - Las Vegas, NV

PRINCIPAL INVESTIGATOR: Mr. Eric Koglin

FY 1999 FUNDS: $20K

OBJECTIVE: The goal of this project is to evaluate, and report on innovative and alternative monitoring, measurement and site characterization technologies in support of the Department of Defense (DoD) National Environmental Technology Test Sites (NETTS) program. The results of this effort will facilitate the acceptance and use of cost-effective technologies applicable to a wide range of environmental problems, particularly focusing on hazardous waste site assessment, characterization, and monitoring. There is a clear need to ensure that better, faster, and less expensive technologies are available for cleaning up Installation Restoration Program (IRP) and Base Realignment and Closure (BRAC) sites. Achieving cost-effective site cleanup is in everyone's best interest. However, currently there is a long lag time between the successful field demonstration of a new technology and its routine use. This lag time will likely continue unless a concerted effort is made to advance innovative and emerging technologies. It is also apparent that without active involvement by the Environmental Protection Agency (EPA), the emergence and use of new technologies will continue only slowly. An objective of this demonstration program is to facilitate acceptance by regulators and to develop a data base of information relating to these new technologies.

BENEFIT: Savings in site cleanup will reduce the need for new or additional Federal taxes to support federally funded cleanups. Lower costs for cleanups funded by private parties should reduce inflationary pressures. The NETTS demonstration program will provide a central conduit to channel new technologies to the marketplace more expediently than current methods. Investment capital should be easier to obtain because the developer will have a technology acceptance road map to show to investors. The focus of this project is to support the use and implementation of new technologies by rapidly introducing them to the user community through training, field trial, and direct application at current sites. This demonstration activity is designed to: maximize information transfer and reduce duplication; provide assistance to public and private sector users and developers; support the diffusion of technologies derived from basic and applied Research and Development (R&D) programs; and be a collaborative effort.

TECHNICAL APPROACH AND RISKS: NERL supports the DoD NETTS program by providing planning support for the demonstration of site characterization technologies developed by SERDP or other

technology development sponsors (where the technology can be used to support a DoD requirement). NERL is also responsible for producing guidance on how to conduct and evaluate these types of technologies; providing support to the other National Test Locations Managers in conducting demonstrations; and for managing and disseminating information on demonstrated technologies.

ACCOMPLISHMENTS: In FY98, this project continued to sustain the EPA-led portion of the NETTS for facilitating the development, commercialization, and use of innovative monitoring, measurement, and site characterization technologies. NERL has supported the planning and administering of demonstrations of SERDP-developed technologies for site characterization and monitoring technology, as well as technologies funded by other sources. NERL has also continued to produce guidance on how to conduct and evaluate these types of technologies, and for managing and disseminating information on demonstrated technologies.

TRANSITION: This project will continue to support the transition of technology as defined by the NETTS Mission Statement, which reads: Provide accessible, well-supported field locations for proof-of-principle, applied research, and comparative demonstrations and facilitate transfer of innovative environmental technologies from research to full scale use.

PROJECT SUMMARY

PROJECT TITLE & ID: Explosives Conjugation Products in Remediation Matrices; CU-715

RESEARCH CATEGORY: 6.1 Basic Research

LEAD AGENCY: U.S. Army

LAB: Waterways Experiment Station - Vicksburg, MS

PRINCIPAL INVESTIGATOR: Dr. Judith Pennington

FY 1998 COMPLETED PROJECT

OBJECTIVE: During investigations of potential treatment technologies for explosives-contaminated soils, specifically during bioslurry treatability studies and composting, TNT has been observed to interact with some components of the treatment matrix in such a way as to preclude extraction with organic solvents. Similar interactions have been observed in explosives-amended soils: mass balance determinations using radio-labeled TNT reveal that the radioactivity is still present in the matrix in some unknown form. As much as 80 percent of the radioactivity added to tests is accounted for in the unextractable matrix. Therefore, the parent compound has not been completely destroyed, but has changed to a more complex form. The long-term stability and environmental safety of these uncharacterized conjugates are unknown. Objectives of this basic research include characterization of these explosives conjugates, development of an analytical methods for identifying them in treatment systems and in soils, and determining the long-term stability and environmental safety of the conjugates. Accomplishment of these objectives will ensure the development of effective remediation technologies that ameliorate environmental health effects and lead to a more complete characterization of the end products of new treatment technologies. Research was initiated to determine the basic mechanisms of interactions between TNT and humus, soil enzymes and clays under SERDP in FY93. This proposed research intends to expand upon that effort.

BENEFIT: The Department of Defense (DoD) places a high priority on development of truly effective remediation technologies for explosives-contaminated soils and groundwater. Nevertheless, most current technologies fail to demonstrate complete destruction of explosives. Rather, explosives are transformed to related conjugation products that are recalcitrant to further characterization. Although these products are suspected of being relatively unavailable for transport or toxicity in the short term (weeks to months), their ultimate fate in the long term (years) is unknown. This lack of understanding of the ultimate fate of explosives severely limits the credibility of certain remediation technologies. This study will improve existing and future remediation technologies by identifying the types of chemical bonding and potential environmental impacts of explosives conjugates in remediation matrices.

ACCOMPLISHMENTS: In FY98 spike-recovery studies using compost, sand and digester sludge were completed. Results of all the testing to date on solvent extractable and hydrolyzable explosives and their transformation products in compost and digester sludges are being compiled into a U.S. Army Cold Region

Research and Engineering Laboratory (CRREL) Special Report. Additional analytical tests were under development to measure the capacity of a bioremediation matrix for binding of TNT transformation products. For the nuclear magnetic resonance (NMR) spectra, time-series incubations of amino and diamino transformation products with whole peat is still continuing. Solution phase analyses have been conducted by CRREL while the incubations and NMR spectra were conducted by the U.S. Geological Survey (USGS). In addition, results from the microbial degradation studies indicated incorporation of as much as 5% of the radiolabel from TNT (added to soil prior to composting) into bacterial glycolipids. This confirms a limited amount of bacterial uptake and processing of the contaminant during composting. An alkaline-unwinding assay for DNA single strand breakage was also adapted for application to earthworms. The assay measures genotoxicity quantitatively and is an indication of a direct impact of chemicals on genetic material. Results obtained with earthworms exposed to uncomposted TNT were negative which is consistent with our previous studies showing a low order of mutagenicity of TNT. Tests with composted material are in progress.

TRANSITION: This project will transition widely to DoD sites contaminated with explosives. Acceptance of remediation technologies will be enhanced with regulatory agencies and other users concerned with the ultimate safety and environmental effects of explosives. Furthermore, an understanding of the nature and properties of conjugation products will lead to new and improved approaches to remediation.

PROJECT SUMMARY

PROJECT TITLE & ID: Federal Integrated Biotreatment Research Consortium (FIBRC): Flask to Field Initiative; CU-720

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Army

LAB: Waterways Experiment Station - Vicksburg, MS

PRINCIPAL INVESTIGATOR: Mr. Jeffrey W. Talley

FY 1999 FUNDS: $2,250K

OBJECTIVE: The objective of this project is to develop a set of "realistic" biotreatment processes for the cleanup of several classes of contaminants at Department of Defense (DoD) sites. A single, panacea technology for each contaminant group that can be used at all DoD sites will not be obtained. All treatment processes have technical and economic limitations, and part of the experimental process of this program will be to define these limitations.

BENEFIT: The primary benefit of this study is reduced remediation costs associated with development of "realistic" biotreatment processes for the cleanup of contaminated DoD sites. Secondary benefits include: expanded implementation potential of existing and developing biotreatment processes, biotreatment technologies that result in the on-site destruction of contaminants, and increased regulatory and user acceptance.

TECHNICAL APPROACH AND RISKS: The technical approach of this project will be to continue to investigate a variety of promising biotreatment processes at the bench and intermediate scale. The experiments in this program will be directed toward four major research areas: 1) biological treatment of explosives, 2) chlorinated solvents, 3) polychlorinated biphenyls (PCB), and 4) polycyclic aromatic hydrocarbons (PAH). The planned experiments represent up-to-date techniques with the potential for reducing treatment costs at DoD sites. In some cases, the concepts under investigation have been developed by members of this consortium. In other cases, other concepts that indicate promise were taken from current literature and professional affiliation. Considerable efforts have been made and will continue to be made to ensure that the approach is always up-to-date. The technical approach and processes under development have the potential to be fielded within a reasonable amount of time. This approach will ensure that the DoD will have more cost-effective remediation technology within time frame required for DoD site remediation activities.

Biotreatment processes will be evaluated for the following four major contaminant groups:

EXPLOSIVES CONTAMINATED SOILS AND GROUNDWATERS - A variety of promising biotreatment techniques will be investigated for remediation of soil and groundwater contaminated with explosives compounds. Explosives contamination represents one of the most prevalent types of organic contamination within the DoD. The following biotreatment mechanisms will be investigated for explosives: 1) Discovery of Novel Enzymatic Reactions and Determination of Biodegradation Mechanisms and Pathways, 2) Phytoremediation of Explosives Contaminated Groundwater using Wetlands and Aquatic Plants, 3) Phytoremediation of Munitions Contaminated Soils, Enhanced TNT Biodegradation Through Genetic Manipulation.

PAH CONTAMINATED SOILS - This group of contaminants represents the most regulated of PAH compounds due to their carcinogenic properties. Also, because of their large and complex molecular structure, they also represent the most difficult of all the PAHs to biologically degrade. Key research issues are: 1) Heavy Molecular Weight PAH Biodegradation, 2) Mass Transfer and Bioavailability Enhancement for In-Situ Intermittent Slurry Reactor Treatment of Dense Non-Aqueous Phase Liquid (DNAPL)-Contaminated Soils.

CHLORINATED SOLVENT CONTAMINATED SOILS AND GROUNDWATERS - Chlorinated solvents represent a class of contaminants that is detected at more DoD sites than any other contaminant group. Issues under investigation for chlorinated solvents within this program include: 1) Electrically Activated Reductive Dechlorination of Chlorinated Solvents, 2) Distinguishing the Microbial Communities Active in the Enhanced Aerobic Treatment of Chlorinated Ethenes, 3) Phytoremediation of Shallow Chlorinated Solvent Plumes: Engineered Tree Planation and Transgenic Trees to Secrete Dehalogense Enzymes.

PCB CONTAMINATED SOILS - Soils contaminated with PCBs represent one of the most challenging compound groups under investigation in this project. PCBs are found at many DoD installations due to improper disposal of hydraulic fluids and waste lubricating oils. Primary issues under investigation are: Enhancing PCB Biodegradation.

ACCOMPLISHMENTS: In FY98, the fluidized-bed technology for biodegradation of mixtures of 2,4- and 2,6-dinitrotoluenes in contaminated groundwater was field-tested. The VAAP fluidized bed reactor became operational. The project studied the bed reactor for 9 months to allow for a complete evaluation of scale-up issues at this scale of operation. Throughout the year the consortium has been actively progressing towards the completion of the year's milestones. Many of these accomplishments are ongoing and will proceed into FY99. The consortium has been continually working with the Technical Advisory Committee to ensure that this initiative progresses in a timely manner.

TRANSITION: This project has a transition plan that plans to develop for the DoD community a biotreatment "toolbox" that can be drawn upon to offer the right process for each site. The technology produced by this project is intended to serve remediation project managers want options and well defined limitations of each option made available to them during their remediation efforts. Each process, whether it is traditional or innovative, has technical limitations and risks associated with its fielding. The knowledge of these process limitations will be required to reduce the risks accepted by the installation and regulatory agencies to an acceptable level.

PROJECT SUMMARY

PROJECT TITLE & ID: National Environmental Technology Test Sites (NETTS) Program — McClellan AFB, CA; CU-861

RESEARCH CATEGORY: 6.4 Demonstration and Validation

LEAD AGENCY: U.S. Air Force

LAB: McClellan Air Force Base - Sacramento, CA

PRINCIPAL INVESTIGATOR: Mr. Phillip Mook

FY 1999 FUNDS: $220K

OBJECTIVE: The National Environmental Technology Test Site (NETTS) program goal is to enable efficient demonstration of candidate detection, monitoring or cleanup technologies, either on an individual basis or in parallel with similar projects, under representative hydrological and climate regimes as found at many contaminated sites in the Department of Defense (DoD). Current environmental cleanup technologies are costly, slow, and largely ineffective. The NETTS program will provide test beds for research to fully understand the mechanisms in proposed treatment processes. The NETTS National Test Location at McClellan Air Force Base (AFB) provides test sites to investigate technologies for treatment of unsaturated soils and extracted soil-gas contaminated with chlorinated solvents, as well as ex-situ treatment of contaminated groundwater. As part of its cleanup effort, McClellan AFB has been well characterized.

BENEFIT: Test locations are fully characterized and monitored areas where new technologies can be quickly and effectively demonstrated. This will save time and money for technology demonstrations by providing on-site management, pre-characterization, and more timely permitting. An established, dedicated test site will enable technology demonstrations to be performed at a cost lower than that of a one-time demonstration elsewhere.

TECHNICAL APPROACH AND RISKS: As a NETTS test location, McClellan AFB provides a well-characterized demonstration site for applied research, demonstration, and evaluation of promising cleanup and monitoring technologies. McClellan AFB currently has four operational and two planned Soil Vapor Extraction (SVE) Systems. All systems have dedicated utilities adjacent to them allowing for convenient slip-stream demonstrations. McClellan AFB's groundwater treatment plant currently services 23 extraction wells. The SVE systems and groundwater treatment facility provide opportunities for demonstrating in-situ and ex-situ techniques for remediating soils and groundwater contaminated with solvents. There are more than 375 groundwater monitoring wells located on and around McClellan AFB.

ACCOMPLISHMENTS: In FY 98, The McClellan Air Force Base NETTS location successfully co-sponsored the first annual conference on remediation of chlorinated and recalcitrant compounds. Other

accomplishments included: sponsored a visitor's day for an Environmental Protection Agency (EPA) Environmental Technology Verification (ETV) program groundwater sensors project; published 3 papers in FY98; provided information and served as test case for EPA ETV Decision Support Software and DOE Plume Study program; issued 5 final work plans for FY 98 new start projects; issued technology application analysis reports for 2 FY 98 project completions; provided support to PIs for work plan development for 3 FY 98 new start projects; provided infrastructure and regulatory compliance support to 19 on-going and new start projects.

TRANSITION: This project will continue to support the transition of technology as defined by the NETTS Mission Statement that reads: Provide accessible, well-supported field locations for proof-of-principle, applied research, and comparative demonstrations and to facilitate transfer of innovative environmental technologies from research to full scale use.

PROJECT SUMMARY

PROJECT TITLE & ID: National Environmental Technology Test Sites (NETTS) Program — Naval Construction Battalion Center (CBC), Port Hueneme, CA; CU-863

RESEARCH CATEGORY: 6.3 Advanced Development

LEAD AGENCY: U.S. Navy

LAB: Naval Facilities Engineering Service Center - Port Hueneme, CA

PRINCIPAL INVESTIGATOR: Mr. Ernest Lory

FY 1999 FUNDS: $670K

OBJECTIVE: The objective of the Navy Construction Battalion Center (CBC) National Environmental Technology Test Sites (NETTS) National Test Location (NTL) at Port Hueneme, CA, is to support demonstration of systems for characterizing and remediating soil, sediments, and groundwater contaminated with fuel hydrocarbons and/or waste oil. It provides test sites to investigate both ex-situ technologies for treatment of soils and in-situ technologies for groundwater contaminated with fuel hydrocarbons.

BENEFIT: The NTL for fuel hydrocarbon and waste oil provides well characterized test locations, controlled field conditions for comparative evaluations of technologies, uniform evaluation criteria for demonstrations, reporting of results and technology transfer, and cost savings through amortization of infrastructure and management.

TECHNICAL APPROACH AND RISKS: The Test Location Manager (TLM) at CBC, Port Hueneme will provide programmatic, infrastructure and technical support to NETTS for fuel hydrocarbon and waste oil characterization and remediation demonstrations. Programmatic support will include integration of the following: (1) Quality Assurance/Quality Control (QA/QC) procedures, (2) test protocol guidance, (3) demonstration reporting format, and (4) environmental setting, cost-and-performance data retrieval guidance. Infrastructure and its management (operation and maintenance) will include: (1) monitoring wells, (2) in-line sensor network, (3) ex-situ treatment facility with hazardous material handling capability, (4) utilities, (5) contaminated soil, sediments and groundwater resources. Technical support will include: (1) characterizing and monitoring contaminants, (2) processing permits, (3) supporting stakeholder involvement, and (4) transferring technologies.

ACCOMPLISHMENTS: In FY98, the Port Hueneme NETTS test location provided: (1) Maintenance of infrastructure during severe storm periods and conducted regulatory agencies water and air sampling requirements, (2) did site recovery after storms and restored security of sites and coverings of soil piles, (3) completed air and water monitoring sampling and report preparation, (4) decommissioned four SERDP test wells, and (5) supported infrastructure and safety operation of four major projects.

TRANSITION: This project will continue to support the transition of technology as defined by the NETTS Mission Statement that reads: Provide accessible, well-supported field locations for proof-of-principle, applied research, and comparative demonstrations and to facilitate transfer of innovative environmental technologies from research to full scale use.

PROJECT SUMMARY

PROJECT TITLE & ID: National Environmental Technology Test Sites (NETTS) Program — former Wurtsmith AFB, MI; CU-864

RESEARCH CATEGORY: 6.3 Advanced Development

LEAD AGENCY: U.S. Environmental Protection Agency

LAB: University of Michigan, National Center for Integrated Bioremediation Research & Development - Oscoda, MI

PRINCIPAL INVESTIGATOR: Dr. Michael Barcelona

FY 1999 FUNDS: $400K

OBJECTIVE: The objective is to operate and maintain a National Environmental Technology Test Sites (NETTS) National Test Location at the National Center for Integrated Bioremediation Research and Development (NCIBRD) which investigates advanced technologies in site characterization, decontamination of hazardous wastes, and remediation of spill and disposal sites. Under NETTS, well-characterized test sites will be provided for technologies with evident promise for complete and cost-effective remediation with minimal environmental disruption, which are favored for facility usage. These technologies involve on-site and in-situ processes which integrate biological and physicochemical methods for treatment of soils and groundwater contaminated with fuels, chlorinated solvents, and organic mixtures. NCIBRD is located at the recently decommissioned Wurtsmith Air Force Base (AFB) in Oscoda, Michigan, which has numerous fuel and chlorinated solvent contamination sites resulting from former Air Force activities.

BENEFIT: This test location provides significant direct and indirect benefit to the Department of Defense (DoD), Department of Energy (DOE), and Environmental Protection Agency (EPA) environmental Research and Development (R&D) programs by enabling advanced site characterization and remediation technologies to be evaluated on a common baseline. It also provides a standardized testing procedures and cost-and-performance evaluation guidelines which should expedite the approval process for new technologies and in turn facilitate the transfer of those technologies from the development stage to operational use. Field-scale testing at sites which are well characterized and monitored on a continuing basis will save considerable amounts of money in evaluating individual technologies for DoD use.

TECHNICAL APPROACH AND RISKS: Activities at NCIBRD include an array of research, development, demonstration, testing and evaluation efforts toward the transfer of field and laboratory findings into successful remediation practice. The program focuses on several specific problems relating to the development of core biotechnologies such as the enhanced understanding of microbiology and microbial geochemistry, improved means for implementing biotechnology in engineering applications, and accelerated bioremediation of contaminated soils and groundwater. Controlled programs on site characterization and in-situ integrated remediation technologies for decontamination of hazardous

substances in wastes, soils, and groundwater are conducted at the facility. The majority of the sites at the base have been characterized to some extent. Several of the larger sites are under hydraulic control by way of pump-and-treat systems. A subset of three fuel and chlorinated solvent sites have been characterized geochemically and microbially in support of in-situ bioremediation. The facilities provide a focal point for coordination and cooperation within the broad community of institutions, agencies, and corporations currently attempting to develop these technologies.

ACCOMPLISHMENTS: The Wurtsmith NETTS test location successfully provided support for the second reactive tracer test at MIRTL was identified from a private company and the American Petroleum Institute. The experiment began in 4/98 involving the release of a BTEX and MTBE mixture to be followed by adjustment of oxidation-reduction conditions to enhance microbial transformation and intervene with a chemical oxidant as a backup. Approvals for the extraction, EFX bioreactor treatment, and reinjection of VOC contaminated ground-water from the FT-02 site were received from the USAF-BCA, MDEQ, and EPA. The in-situ treatment cells have been constructed, instrumented and sampled. A tracer test was performed which verified the performance of the recirculation system. The bioreactor was seeded with microorganisms and the system became fully operational. The EGR/NCIBRD Web Site was established and is supported by a Windows NT, Access driven system.

TRANSITION: This project will continue to support the transition of technology as defined by the NETTS Mission Statement that reads: Provide accessible, well-supported field locations for proof-of-principle, applied research, and comparative demonstrations and to facilitate transfer of innovative environmental technologies from research to full scale use.

PROJECT SUMMARY

PROJECT TITLE & ID: National Environmental Technology Test Sites (NETTS) Program—Dover AFB, DE; CU-866

RESEARCH CATEGORY: 6.3 Advanced Development

LEAD AGENCY: U.S. Air Force

LAB: Air Force Research Laboratory - Tyndall Air Force Base, FL

PRINCIPAL INVESTIGATOR: Ms. Alison Lightner

FY 1999 FUNDS: $880K

OBJECTIVE: This NETTS National Test Location, which is managed by the Air Force Research Laboratory, provides test sites for the application of characterization and remediation technologies to soil and water contaminated by chlorinated solvents. Its centerpiece is the Groundwater Remediation Field Laboratory (GRFL). The GRFL consists of isolated, well-monitored, in-situ controlled release test cells, in which mass-balance studies of the fate, transport and remediation of Dense Non-Aqueous Phase Liquids (DNAPLs) may be performed, weather protection, office space and a small analytical laboratory.

BENEFIT: The GRFL is a unique resource, the primary purpose of which is to provide contained release cells for DNAPL research and development that avoid making the gross assumptions that would be necessary if experiments were conducted in previously contaminated aquifers. DNAPLs are immiscible with and denser than water, and when spilled on the ground, migrate below the water table. Once below the water table, they are difficult to locate and remove. Currently there are no acceptable methods for removing or treating DNAPLs. These technologies must be developed to protect the public from the potential health risks associated with DNAPLs in drinking water.

TECHNICAL APPROACH AND RISKS: Operations consist of long-term monitoring of the site, as well as project support to include injection of the constituent (Trichloroethylene primarily), demonstration of innovative technologies, and disposal of a minimal amount of waste from the tests. The GRFL program consists of construction of a maximum of five test cells spaced approximately 50 feet apart and constructed and operated in a way to minimize the potential for environmental contamination. Basic design consists of interconnected, steel barrier piling sections (2 feet width) forming a rectangular pattern (test cells will range in size up to 1800 square feet). By driving the sheet piling 3-5 feet into the clay aquitard (approximately 30 - 40 feet from the surface), a coffer is formed which prevents vertical and lateral migration outside the confines of the box. There is an additional secondary containment coffer surrounding the primary coffer, which is similarly sealed at the bottom and at each joint. The annulus between the cells is filled with water to produce an inward hydraulic gradient. The annulus and inner cell are continuously monitored for leakage. There are both upgradient and downgradient monitoring wells outside the secondary coffer. Other sheet pile designs to be considered include geomembrane and grout type barriers. Risks are minimal for the program as designed and can be controlled. Primary risk is that introduced

material will escape and contaminate an aquifer. Vertical migration is retarded very well by a twenty foot thick underlying clay layer with a hydraulic conductivity four orders of magnitude less than the overlying strata. Double sheet piling, grouting, monitoring, developing emergency pump-and-treat system, and distance to the nearest potential users of the aquifer virtually eliminate the risk from lateral migration. A worst-case risk analysis has shown that risk of significant aquifer and surface water contamination and human health impact is negligible even if no barriers are emplaced, cleanup is not attempted, and the TCE source area is left in place indefinitely. The process for obtaining permits for contained releases has been worked out and it is expected to take less than 90 days per permit application.

ACCOMPLISHMENTS: The Dover NETTS test location successfully completed the InSitu Cooxidation Project conducted in test cell #1. Permit to release 100 Liters of DNAPL was approved and six-demo EPA/SERDP series have begun. DNTS began to perform the extensive additional monitoring/analysis for the new permit. Rehabilitation of Cell #1 was completed to accommodate the Bioenhanced In-Well Vapor Stripping demonstration. DNTS hosted visits from the EPA Region III Remedial Program Managers, and scientists from Germany as part of a US/German Data Exchange Agreement. DNTS produced an exhibit for the 1st International DNAPL Conference at Monterrey, CA. The site has provided groundwater and soil to Wright State University, Stanford, U of Connecticut, U of Oklahoma, and North Carolina A&T State University for various projects.

TRANSITION: This project will continue to support the transition of technology as defined by the NETTS Mission Statement that reads: Provide accessible, well-supported field locations for proof-of-principle, applied research, and comparative demonstrations and to facilitate transfer of innovative environmental technologies from research to full scale use.

PROJECT SUMMARY

PROJECT TITLE & ID: Natural Attenuation of Explosives in Soil and Water Systems at DoD Sites; CU-1043

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Army

LAB: Waterways Experiment Station - Vicksburg, MS

PRINCIPAL INVESTIGATOR: Dr. Judith C. Pennington

FY 1998 COMPLETED PROJECT

OBJECTIVE: Natural attenuation may be an attractive alternative to more expensive remediation technologies at sites that meet well-defined selection criteria, acceptable risk levels, and that satisfy specific regulatory concerns. However, a significant unanswered question associated with natural attenuation is what processes are relevant and require monitoring to assure that attenuation is effective. Application of existing biomarker and stable isotope technology to in-situ monitoring for natural attenuation of explosives holds the greatest promise for addressing this question. Specific objectives of this project are to (a) identify partner(s) for investigating potential biomarkers, (b) initiate development of mesocosms, and (c) develop an approach for the application of stable isotopes to natural attenuation monitoring.

BENEFIT: Development of effective biomarkers for monitoring natural attenuation will permit application of this technology to sites meeting appropriate selection criteria. Cost of pump-and-treat remediation is approximately $300 per ton, while natural attenuation cost is estimated to be $30 per ton. In addition to the significant cost-saving potential, this project will provide support for and become an integral part of an ESTCP-funded effort for demonstrating natural attenuation of explosives.

ACCOMPLISHMENTS: In FY98, results of studies to verify earlier FY97 result indicate that as extractable TNT concentrations decrease over time in soil mesocosms, the stable isotope ratios of carbon and nitrogen remain unchanged. The sampling protocol has been finalized and implemented with the ten sampling rounds at Joliet Army Ammunition Plant (JAAP) and will be followed at Crane Naval Surface Warfare Center and in an extended sampling program at Louisiana Army Ammunitions Plant (LAAP). Site specific rate and capacity parameters for explosives determined in LAAP groundwater were incorporated into the existing modeling codes. These parameters were used in the modeling of groundwater at JAAP as well as at LAAP. Results for JAAP are included in the draft completion report submitted to the Industrial Operations Command, Rock Island, IL. Three tests have been developed to assess microbial degradation potential of TNT and RDX contaminated sites. These include a mineralization radioassay, lipid biomarker analyses and nucleic acid biomarker analyses. These tests have been integrated into the draft A Protocol for Evaluation and Implementation of Natural Attenuation at

Explosives-Contaminated Sites. A complete description of site geology based upon well and CPT data has been completed for LAAP and JAAP.

TRANSITION: This project will transition widely to Department of Defense (DoD) sites contaminated with explosives. The development of effective biomarkers for monitoring natural attenuation will permit application of this technology to sites meeting appropriate selection criteria. Furthermore, appropriate selection criteria will lead to enhanced acceptance of remediation technologies with regulatory agencies and other users concerned with the ultimate safety and environmental effects of explosives.

PROJECT SUMMARY

PROJECT TITLE & ID: Application of Neural Networks Coupled with Genetic Algorithms to Optimize Soil Cleanup Operations in Cold Climates; CU-1049

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Army

LAB: Cold Regions Research and Engineering Laboratory - Hanover, VT

PRINCIPAL INVESTIGATOR: Dr. John M. Sullivan

FY 1998 COMPLETED PROJECT

OBJECTIVE: This project has two objectives for site characterization and contaminant fate, transport, and remediation analysis for site cleanup alternatives. The first objective is automated decomposition of Ground Penetrating Radar (GPR) signals into stratigraphic layers using Neural Networks (NNs). GPR can probe the subsurface non-invasively at high resolution but methods to quantitatively interpret these data are sparse. We propose to train NNs, which are ideally suited for pattern recognition, to recognize various stratigraphic layer configurations. This tool will allow enhanced quantitative site conceptualization. The second objective is to develop and implement a rapid solution strategy to analyze selected remediation/monitoring alternatives using NNs coupled to Genetic Optimization (GO) routines. The NNs will be trained to recognize contaminant distributions as a function of boundary conditions. The GO routines will be developed for decision analysis of remediation alternatives and monitoring strategies based on the simulated behavior predicted by the NN. The coupling of these applied research areas can potentially yield an analysis technique for characterizing subsurface stratigraphy and the selection of an optimum remediation strategy.

BENEFIT: The expected benefits of this project are an accurate, non-invasive tool for site conceptualization and an optimized remediation and monitoring deployment plan for sites requiring cleanup and monitoring of groundwater. The ability to characterize a site will increase by two orders of magnitude from current practices and gains realized in predicting subsurface contaminant flow would be an order of magnitude. Optimized deployment routines could reduce remediation and monitoring cost of a contaminated site by one third.

ACCOMPLISHMENTS: In FY98, this project successfully developed a preliminary framework for and demonstrated PC based Windows application of NN and CLI programs. Established Phase-2 objectives and directions for merging CLI and NN programs into one orchestrated system and the Windows based NN and CLI program demonstrated for multiple GPR input situations. Completed interim report delineating the advances of CLI and NN.

TRANSITION: The project intends to transition the optimized deployment routines to be developed and tested under this project beyond the cold regions applications to many contaminated sites.

PROJECT SUMMARY

PROJECT TITLE & ID: Development of Simulators for In-Situ Remediation Evaluation, Design, and Operation; CU-1062

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Army

LAB: Waterways Experiment Station - Vicksburg, MS

PRINCIPAL INVESTIGATOR: Dr. Mark Dortch

FY 1999 FUNDS: $765K

OBJECTIVE: The ultimate goal in remediation modeling is to minimize remediation costs and environmental and human risks while maximizing cleanup. Toward this end, the general goals of this project are: (1) to develop reliable simulators for promising technologies of interest to Department of Defense (DoD), Department of Energy (DOE), and the regulatory community, and (2) to provide efficient access to multiple remediation simulators through a common user environment amenable to multi-disciplinary cleanup teams. A common, graphical user environment has been developed for these simulators; it is the DoD Groundwater Modeling System (GMS). The GMS provides conceptualization, parameterization, visualization, and animation capabilities. Additionally, GMS extensions, either ongoing or planned, will provide capabilities for conducting remediation, uncertainty, optimization, and cost analyses. The primary technical objectives of this project are to: (1) develop/enhance state-of-the-art remediation simulators for the following technologies: in-situ bioremediation; surfactant-enhanced bioremediation; electrokinetic-enhanced bioremediation; electrokinetic-enhanced mobilization of metals; natural attenuation of petroleum hydrocarbons; natural attenuation of explosives; in-situ chemical treatment; surfactant/cosolvent flushing to recover Non-Aqueous Phase Liquids (NAPLs); soil vapor extraction and bioventing; and air sparging; and (2) verify these simulators against available laboratory and field data; and (c) incorporate these simulators into the GMS to provide DoD, DOE, and other users with the computational ability to assess the tradeoff between environmental risk (cleanup level) and cost-effectiveness for a variety of cleanup technologies prior to their implementation.

BENEFIT: The GMS-based simulators will permit efficient evaluation of multiple remediation technologies for site-specific conditions, allowing selection of effective and cheaper cleanup actions. Such simulators are needed to support advocacy for biogeochemically complex alternatives that are faster, more effective, and/or more cost-efficient than traditional methods. Simulators will improve the remedial design by permitting cleanup specialists to consider multiple scenarios that could increase cleanup effectiveness.

TECHNICAL APPROACH AND RISKS: Remediation simulator development will proceed along three paths, in order of priority: (1) utilize existing, proven remediation simulators where available and consistent with project goals, (2) modify promising groundwater codes to simulate additional technologies

as appropriate, or (3) develop new codes as required for efficient simulation of innovative technologies. All simulators will be verified against available laboratory and field data. Where data permit, the simulators will be applied for National Environmental Technology Test Sites (NETTS). Results of these evaluations and the simulator codes will be documentation. Each simulator will be implemented in the GMS. This project strongly leverages technical partnering and collaboration with ongoing and proposed basic and applied research in subsurface flow, contaminant fate/transport, remedial methods, remediation simulation under heterogeneous subsurface conditions, GMS-user environment development, and high performance computing in environmental quality modeling. Technical risk issues involve: (1) uncertainty regarding key processes in complex remediation technologies; (2) the scarcity of experimental or field data for innovative technologies; and (3) the general adequacy of differing computational resources on which to run complex models efficiently. Leveraging against the new Common High-Performance Scalable Software Initiative and Army High-Performance Computing efforts will address several of the high-performance computing issues associated with simulator development and execution.

ACCOMPLISHMENTS: In FY98, the U.S. Army Waterways Experiment Station (WES) researchers have worked toward developing and verifying the various modeling codes. Corrective Action Plan Reports and Site Investigation Reports on Hill Air Force Base bioventing remediation sites, site 870, site 260 and site 280, were received. Data from all sites were reviewed, and it was decided to use site 280 as the field case for modeling bioventing processes using the NUFT3D code. Requested and received reports on Site 280 date back to 1991. Data was compiled on site characterization, soil properties, pre-and-post-remediation concentrations, respiration tests, remediation system operation, and other necessary data to begin preliminary modeling using representative input parameters. Monod kinetics were incorporated into the NUFT code. The option is very general and has the capability for multiple Monod rate laws with multiple inhibition factors. NUFT input files were then developed to include bioventing input parameters. The model has a 300 ft wide and approximately 110 ft thick cylindrical (radially symmetric) domain, centered at the bioventing injection well. The model includes multiphase, multicomponent transport with dual Monod kinetics for biodegradation of fuel hydrocarbons. Modifications to OS3D were completed in the following areas: 1)incorporation of intra-aqueous reaction kinetics into the code, while retaining the option of assuming equilibrium with respect to these reactions; 2) revision of the database routine so that the full range of possible aqueous complexation and mineral-water reactions can be included automatically; 3) modification to the OS3D input file so that it is based on keywords rather than required inputs; and 4) incorporation of additional rate laws like the Monod expressions used for microbially-mediated reactions. New data from the re-packed columns at the Dover AFB Funnel and Gate Site are being analyzed and show behavior that is more in line with other studies of zero-valent iron treatment systems. There is still indication that the efficiency of the iron reactivity is diminishing over time. Model simulations will resume following receipt of the rest of the data.

TRANSITION: The project will transition the GMS-based simulators directly to users that include DoD, DOE, EPA, and other groundwater and environmental professionals involved in hazardous waste site cleanup. Use of these remediation simulators will allow more reliable comparison between cleanup level (its duration, environmental risk level) and the cost of each level of cleanup.

PROJECT SUMMARY

PROJECT TITLE & ID: Bioenhanced In-Well Vapor Stripping to Treat Trichloroethylene; CU-1064

RESEARCH CATEGORY: 6.3 Advanced Development

LEAD AGENCY: U.S. Air Force

LAB: Air Force Research Laboratory - Tyndall Air Force Base, FL

PRINCIPAL INVESTIGATOR: Dr. Mark N. Goltz

FY 1999 FUNDS: $200K

OBJECTIVE: The objective of this project is to demonstrate the potential of combining two innovative, recently demonstrated, remediation technologies, in-well vapor stripping and in-situ aerobic cometabolic bioremediation, to cleanup an area contaminated with separate phase [Dense Non-Aqueous Phase Liquid (DNAPL)] and dissolved phase Trichloroethylene (TCE).

BENEFIT: The most obvious benefit is that this combination of technologies offers the potential of reducing, in-situ contaminant concentrations at a DNAPL contaminated site over three orders of magnitude, something which heretofore has never been demonstrated. The fact that the technologies are applied in-situ minimizes risk to human and environmental receptors, as well as reduces the costs of pumping water to the surface, treating it, and disposing of it. The technologies can be used at sites with any volatile, separate-phase contaminant that is susceptible to bioremediation by aerobic cometabolism (TCE, Dichloroethylene (DCE), vinyl chloride, dichloromethane, etc.).

TECHNICAL APPROACH AND RISKS: Under this project, an in-well vapor stripper will be installed in a DNAPL (TCE) contaminated "hot spot zone", upgradient from a downflow biotreatment well. The TCE will be emplaced in a cell at the Groundwater Remediation Field Laboratory (GRFL) at Dover AFB. In operation, the in-well vapor stripper will use air-lift pumping to pump contaminated water from the lower portion of the aquifer to a screened interval above and below the water table. Approximately 90-99 percent of the volatile organic compound (VOC) will be stripped out of the water into the gas phase, which will subsequently be treated using granular activated carbon. The treated water leaving the upper screen of the in-well vapor stripper will flow to the upper screen of the biotreatment well. Water entering the biotreatment well will be pumped down through the well, where a primary substrate such as toluene will be added. Oxygen may also need to be added in the biotreatment well, though it is possible that the oxygen dissolved during the in-well vapor stripping will be sufficient to support the aerobic bioremediation process. After addition of the primary substrate (and possibly, oxygen), the water will be injected into the aquifer through the lower screened interval, where indigenous microorganisms can aerobically metabolize the primary substrate and cometabolize the contaminant. A portion of the water leaving the bioactive zone will recirculate back to the lower screen of the in-well vapor stripper for further treatment. The combined

technology of bioenhanced in-well vapor stripping should remove as much or more TCE from the groundwater than would be removed compared to conventional technologies (e.g., pump-and-treat).

Because each technology is currently being demonstrated independently, the main technical challenge and risk comes from the integration of the two, which can be dealt with by adjusting various operating parameters (e.g., gas flow in the stripping well, primary substrate feed in the biotreatment well, water flow rates) to optimize performance. Another challenge will be to scale down the two technologies (in-well vapor stripping and in-situ bioremediation), which are currently being demonstrated at full-scale in the field at Edwards Air Force Base (AFB), for analysis within the confines of a GRFL cell. This scaling-down will be accomplished through modeling, by combining fate and transport models that have been developed to simulate the two technologies. A last challenge will be to demonstrate the system at a site that has geochemical conditions considerably different from the conditions encountered at Edwards AFB. In particular, the high iron content in the groundwater at the GRFL may present difficulties that may require adjustments to the system.

ACCOMPLISHMENTS: In FY98, modeling studies were completed that showed concentrations as high as several 100 mg/L of TCE would reach the biotreatment well if the system was operated as originally planned, with both treatment wells pumping at equal rates. As such high levels of TCE cannot be handled in the biotreatment well, a new pumping schedule was devised. This revised schedule called for a phased increase (starting from zero) in the biotreatment well pumping rate. Based on the revised pumping schedule, model simulations show that TCE concentrations reaching the biotreatment well will be in the tens of mg/L.

TRANSITION: If successful in the test cell demonstration, this project will transition to a full scale demonstration that combines the two remediation technologies, in-well vapor stripping and in-situ aerobic cometabolic bioremediation, to cleanup an area contaminated with separate phase (DNAPL) and dissolved phase TCE.

PROJECT SUMMARY

PROJECT TITLE & ID: Low-Frequency Ultra-Wideband Boom Synthetic Aperture Radar (Boom-SAR) for Remote Detection of Unexploded Ordnance (UXO); CU-1070

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Army

LAB: Army Research Laboratory - Adelphi, MD

PRINCIPAL INVESTIGATOR: Mr. Marc Ressler

FY 1999 FUNDS: $800K

OBJECTIVE: The goals of this project are: 1) to determine the applicability of low-frequency ultra-wideband (UWB) Synthetic Aperture Radar (SAR) for detecting and discriminating surface and subsurface unexploded ordnance (UXO); 2) to refine and validate electromagnetic models that can be used to extrapolate UWB SAR performance to other environmental conditions (soils); and, 3) to develop detection algorithms for separating UXO from clutter.

BENEFIT: The knowledge gained by this effort will significantly enhance our understanding of the phenomenology of UXO characterization using low-frequency UWB SAR. This effort will also help to determine the utility of the Army Research Laboratory (ARL) BoomSAR for surveying large regions and detecting and discriminating various surface and subsurface UXO. It is expected that this technology will achieve rapid survey speeds/coverage rates while allowing safe standoff distances during operation; it will also significantly improve the detection, monitoring, and risk management activities at cleanup sites.

TECHNICAL APPROACH AND RISKS: Currently, methods for detecting UXO involve laborious ground surveys that are slow, dangerous, and impractical for dealing with vast UXO-contaminated lands. Advanced technologies are required which are quicker, safer, and more cost-effective than current approaches. SAR is an advanced technology that offers significant potential for quickly and safely detecting UXO. The ARL will use their precision measurement asset, called the BoomSAR, in the execution of this project. The BoomSAR is a fully polarimetric radar that operates across a 1-GHz-wide band, from 25 MHZ to 1 GHz. This bandwidth contains low frequencies needed for ground penetration, while maintaining higher-frequency coverage for high-resolution imagery. The ultra-wide bandwidth provides measured range resolution of 0.15 m; the aperture length provides cross-range resolution of 0.15 m. The radar is mounted on a boom-lift that can operate at heights of 5 to 45 m while moving at 1 km per hour, allowing the radar to operate in a strip-map SAR mode.

ARL's BoomSAR will be used to collect high-quality precision data to support phenomenological investigations of electromagnetic wave propagation through dielectric media. These investigations, in turn,

will support the development of algorithms for target detection. Data will be collected at two UXO test sites that have been seeded with a comprehensive variety of inert UXO.

This project is minimizing technical risk by leveraging the significant investments of ARL's 6.2 Army tech base and Defense Intelligence Agency customer funds. The ARL has played a significant role in understanding the potential of low-frequency, ultra-wideband synthetic aperture radar (UWB SAR) technology to detect targets concealed by foliage and subsurface targets. In addition, ARL has been working closely with other agencies, such as Defense Advanced Research Projects Agency, Air Force Research Laboratory, Naval Surface Weapons Center, Defense Special Weapons Agency, and Defense Intelligence Agency, to realize the full potential of this advanced technology.

ACCOMPLISHMENTS: In FY98, ARL researchers have used their low-frequency, ultra-wideband (50 MHZ - 1200 MHZ) SAR to enhance the ability to detect buried UXO. Activities have included:

- ➢ Continuing to Processing BoomSAR Data from Yuma Proving Ground Experiments BoomSAR imagery and preliminary results were presented at the SERDP Symposium on 1-3 Dec 98.
- ➢ Completed installation of test targets at UXO test area, Eglin Air Force Base and Established an extensive UXO test site at Eglin AFB Test Area C-62. Coordinated the collection, inspection, and transportation of nearly 7 tons of inert UXO from Yuma Proving Ground to Eglin AFB. Coordinated the collection and inspection of targets made available by Eglin AFB. Finalized the required documentation (Test Directive, Statement of Capability, etc.).
- ➢ Subsurface Ordnance Characterization System (SOCS) characterization of UXO test site at Eglin AFB and recruited Tyndall AFB to survey (at no cost to our project) the entire site using their SOCS. The SOCS data, especially data on non-target areas, aided in resolving unknown targets that might appear in BoomSAR imagery.
- ➢ BoomSAR data collection was started in October 1998. The BoomSAR and related field test trailers and support equipment were shipped to Eglin AFB from Yuma Proving Ground, Aberdeen Proving Ground, and the ARL Adelphi Laboratory Center.
- ➢ Received final report on ARL Federated Lab data collection. The Air Force Research Laboratory, Tyndall AFB submitted a 400-page report (including the 200-page appendix from Ohio State University and Battelle) on the ARL Fed Lab-sponsored multisensor data collection at Yuma Proving Ground.
- ➢ Authored (and co-authored with Duke University) several technical abstracts for the SPIE AeroSense '99 Conference in April, 1999. The abstracts cover work performed under this project as well as various aspects of ARL's Ultra-Wideband Radar tech base program.

TRANSITION: The technology developed under this project will transition to users at active test and training ranges, Base Realignment and Closure (BRAC) and formerly used defense (FUD) sites, and numerous foreign countries requiring advanced technologies for locating UXO.

PROJECT SUMMARY

PROJECT TITLE & ID: Unexploded Ordnance (UXO) Detection by Enhanced Harmonic Radar; CU-1071

RESEARCH CATEGORY: 6.3 Advanced Development

LEAD AGENCY: National Reconnaissance Office

LAB: National Reconnaissance Office - Chantilly, VA

PRINCIPAL INVESTIGATOR: Dr. Ronald Stocks

FY 1999 FUNDS: $260K

OBJECTIVE: The objective of this effort is to design, fabricate, and test a third harmonic radar to determine its efficiency in detecting surface and buried unexploded ordnance (UXO) of all sizes and types. In addition, the radar also will produce a capability to produce high resolution images showing their locations. This proposal builds on earlier work on harmonic radar and outlines the development and demonstration of a high resolution, medium range (3-4 km standoff distance) impulse driven synthetic aperture radar.

The problem of UXO detection has become both acute domestically and worldwide. In the U.S. specifically, there are over 900 sites (11 million acres) of potentially UXO contaminated land of varying terrain, foliation, and topography (including 50 underwater sites). UXO cleanup represents a huge and costly problem. To date, methods of detection and remediation are at best slow and expensive and at worst crude and highly dangerous. The advantage of improved target detection techniques (especially airborne) that can aid in rapid, cost efficient and safe detection are obvious.

BENEFIT: The immediate benefit to be realized from this effort is a prototype system with a demonstrated capability to remotely detect and locate surface and shallow-buried UXO. If successful, this effort will provide the UXO remediation community with a capacity not now available. The radar system will be capable of standoff "broad area" search at relatively low cost and provide greater efficiency in removal and/or cleanup. The radar system will be an operational prototype that could be used for subsequent contractor-supported operations. The radar could also be modified to fit on a variety of aircraft of helicopter platforms. In addition, this technology should be of interest to a variety of other Department of Defense (DoD)/Department of Energy (DOE) environmental, military, and law enforcement objectives.

TECHNICAL APPROACH & RISK: The project is divided into two phases, a ground phase and an airborne phase. The final result of this effort will be a prototype third harmonic radar system hosted on an aircraft for the detection and mapping of surface and subsurface mines and UXO. This system will be available for operational deployment if desired.

The critical elements of this UXO detection system are: 1) the third harmonic returns; 2) the ability to produce usable images for analysis; and 3) the fusion of this information with that from other sensors. The major reason that Ground Penetrating Radar (GPR) and other radars have not lived up to some expectations is not because of the lack of power, resolution or penetration capabilities. Rather, the problem lies with the lack of specificity of the radar return. Natural clutter, depressions, soil strata, etc., produce their own returns that mask, obscure or compete with those targets of interest. Unlike higher frequency radars, typical foliage and ground penetrating radars produce images that are so cluttered that they are difficult to interpret.

Image discriminants have proved elusive and even highly sophisticated Automated Target Recognition algorithms have difficulty in discrimination. Third harmonic radars provide that discriminant. The unique radiation characteristic potentially can be exploited to completely suppress the natural clutter.

The production of images that detect and accurately locate targets of interest has not been previously attempted. However, several years of effort with other radar systems have produced a wealth of image processing algorithms that will form the foundation of the image processing requirement. In addition, this project intends to make use of the SERDP National Environmental Technology Test Sites to the maximum degree possible.

ACCOMPLISHMENTS: In FY97, this project responded to a Scientific Advisory Board (SAB) directive to perform an initial proof-of-concept demonstration prior to pursuing the balance of the project's proposed objectives. Following a successful proof-of-concept, the project continued with its efforts in FY98. These activities included CW chamber measurements being completed and a task measurements report was generated. The ultra wideband (UWB) measurements task has made significant progress throughout the year. The impulse high-voltage system has been calibrated with good overall repeatability and chamber artifacts have been reliably suppressed.

The van-mounted measurement activity has also made significant progress this year. The radar has been assembled, upgraded and tested. Installation of a variable elevation angle antenna system was completed and tested. The antenna system consists of a high voltage transmit horn with a built-in third harmonic suppression filter and two receive horns; one for the fundamental band and one for the third harmonic band. An upgraded fundamental receiver had been assembled for side-by-side (fundamental and third harmonic band) SAR imaging.

TRANSITION: The technology developed under this project will transition to users at active test and training ranges, Base Realignment and Closure (BRAC) and formerly used defense (FUD) sites, and numerous foreign countries requiring advanced technologies for locating UXO.

PROJECT SUMMARY

PROJECT TITLE & ID: Using Mode of Action to Assess Health Risks from Mixtures of Chemical/Physical Agents; CU-1073

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Department of Energy

LAB: Pacific Northwest National Laboratory - Richland, WA

PRINCIPAL INVESTIGATOR: Dr. Richard Bull

FY 1999 FUNDS: $530K

OBJECTIVE: Mixtures of carcinogenic chemicals are a major problem in groundwater plumes and soils on Department of Defense (DoD) and Department of Energy (DOE) facilities. While there is frequently data available for interactions between chemicals to judge risks from short term exposures, data that describes how interactions influence the development of cancer are very rare. This is largely because of the high costs associated with conducting complex interaction studies over the lifetime of experimental animals. Therefore, it is important that the limited resources that are available for studying interactions be directed towards the development of general principles that can be applied to a wide variety of circumstances.

The specific technical objectives: 1) To provide a scientific basis for estimating the risk for liver cancer induction by mixtures of chlorinated hydrocarbon solvents in hazardous waste sites and contaminated groundwater, 2) Test the hypothesis that interactions between non-genotoxic modes of action can be meaningfully predicted from knowledge of the mode of action and the dose-response relationships found with the individual components of the mixture. To limit the cost of this initial effort, the test will be limited to tertiary mixtures in which the dose of only one compound will be varied dichloroacetate (DCA), 3) Based on these studies an experimental design will be developed to validate the approach using solvents that independently generate the metabolites responsible for liver cancer induction.

BENEFIT: Because of the high cost associated with conducting research to examine biological interactions, the study of every potential interaction of environmental concern is not feasible. This research is directed towards the development of general principles that can be applied to a wide variety of circumstances. The benefits to DOE and DoD from the work proposed are: 1) data bases that can be directly used to assess the risks from mixed exposures to DCA or TCA whether they arise as metabolites from a single solvent [e.g., Trichloroethylene (TCE)] or from a mixture of solvents, 2) the data necessary to see how these metabolites interact with a cytotoxic solvent (carbon tetrachloride), and 3) a test of the hypothesis that hazards associated with mixtures of carcinogenic chemicals can be addressed by simply identifying the mode of action and knowing the dose-response relationships for the individual chemicals.

TECHNICAL APPROACH & RISK: The hypothesis this project intends to test is whether classifying the modes of action represented in a mixture and knowledge about the dose-response characteristics involved in eliciting a particular mode of action will provide a simpler and more accurate means of predicting the hazards that the mixture poses over a range of exposure situations. Whereas the number of chemicals present in the mixture may be large, the number of modes of action responsible for these effects are small. Each mode of action may have dozens of mechanisms that might contribute to changes in cell birth/death processes, but establishing mechanisms for every chemical is very expensive. The modes of action represented by the three chemicals proposed for study are general to chemical carcinogenesis. Thus, the approach that would result from proving our hypothesis should be broadly applicable to any mixtures of chemical and/or physical causes of cancer. The top seven chlorinated hydrocarbon solvents found on DOE facilities produce liver cancer by non-genotoxic mechanisms. Two others are clearly genotoxic. Therefore, all modes of action are represented among these compounds. The occurrence of the genotoxic compounds is much less frequent and generally at much lower concentrations than the first seven compounds. Their cleanup levels are less controversial because it is difficult to refute low dose linearity in response for such chemicals and their concentrations rarely exceed drinking water standards of the Environmental Protection Agency (EPA).

ACCOMPLISHMENTS: In FY98, embedding and sectioning of tissues were initiated and completed for all tissues collected to date (DCA/TCA and DCA/TCA mixture studies). Histological staining was initiated for these tissues. Summarization of the tumor yield and size data was initiated. As reported previously, the carbon tetrachloride interaction study (combinations of DCA, TCA, CC14) in initiated mice was terminated because the carbon tetrachloride dose was too high. This resulted in rapid liver tumor development and massive numbers of tumors in the mice. A protocol was developed for repeating the carbon tetrachloride interaction studies at lower doses of carbon tetrachloride. Pharmacokinetics studies were initiated. Seven solvents have been investigated for their ability to produce dichloroacetic acid and trichloroacetic acid as metabolites in mice. Trichoroethylene, tetrachloroethylene, 1,1,2-trichloroethane and 1,1,1,2-tetrachloroethane have been identified as producing either dichloroacetic acid, trichloroacetic acid or both. A protocol has been written and approved for research investigating metabolic profiles after exposure of mice to mixtures of carbon tetrachloride and these 4 solvents.

TRANSITION: The project has a transition plan that includes: 1) insuring utilization of the data through extensive interaction with EPA; 2) establishing the hypothesis that interactions between environmental carcinogens can be understood on the basis of their individual modes of action; and 3) expanding the concept to other important environmental mixtures.

PROJECT SUMMARY

PROJECT TITLE & ID: Value-Added Site Monitoring & Infrastructure Maintenance for In-Situ Bioremediation; CU-1080

RESEARCH CATEGORY: 6.3 Advanced Development

LEAD AGENCY: U.S. Environmental Protection Agency

LAB: University of Michigan, National Center for Integrated Bioremediation Research & Development - Oscoda, MI

PRINCIPAL INVESTIGATOR: Dr. Michael Barcelona

FY 1999 FUNDS: $225K

OBJECTIVE: The objectives of this project include: the continued serial monitoring of intrinsic bioremediation processes at three fuel and solvent contaminated sites at the former Wurtsmith Air Force Base; the support, maintenance, and supplementation of the data in a relational database management system (RDBMS); and the statistical analysis of the data for spatial and temporal variability, estimates of mass removal rates and indicators of bioremediation process change.

BENEFIT: The project will provide direct benefit to Department of Defense (DoD), Department of Energy (DOE), and Environmental Protection Agency (EPA) by: 1) providing comprehensive field data for intrinsic remediation modeling efforts; 2) allowing more cost effective long term monitoring designs to be developed; and, 3) improving basis for collaboration among technology developers which will mean less redundancy between efforts. An overall benefit will be more cost-effective designs and performance goals for bioremediation of contaminated sites.

TECHNICAL APPROACH & RISK: The technical approach consists of a phased approach to the objectives outlined above. State of the art contaminant and geochemical ground-water monitoring will be continued on a quarterly basis at three fuel and solvent contamination sites which have distinct oxidation-reduction zones. Indicators of corresponding bioremediation indicators and the mass of contaminants associated with aquifer solids will be determined as well. Additional, statistical analyses of the time-series and spatial distribution of contaminants and geochemical conditions will be evaluated for sources of error and variability. Bioremediation performance indicators will be developed in selected oxidation-reduction zones. Several years of data exist for the three study sites which will provide a basis for the use of RDBMS and results of the statistical analyses by leading bioremediation modeling and remedial design groups.

ACCOMPLISHMENTS: Internet (internal) and an external web page have been established. Field data has been updated and made more accessible. Laboratory and associated QA/QC data was completed. Presentations and poster sessions on data quality, petroleum hydrocarbon source strength estimates, and

temporal variability of bioremediation indicators have been made. Peer-reviewed papers have been drafted on the latter issues. Permission was granted to proceed with the second tracer test. Negotiation with potential sponsors of the MIRTL2 Natural Gradient Tracer Test proceeded with encouragement.

TRANSITION: The results of the continued serial monitoring of intrinsic bioremediation processes will be made widely available to facilitate transition of the project's efforts. The various efforts to ensure dissemination of information will enable further usage by DoD and DOE site managers.

PROJECT SUMMARY

PROJECT TITLE & ID: Genosensor-Based Ecotoxicity Response Assessment; CU-1081

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Department of Energy

LAB: Oak Ridge National Laboratory - Oak Ridge, TN

PRINCIPAL INVESTIGATOR: Dr. Kenneth Beattie

FY 1999 FUNDS: $780K

OBJECTIVE: The objective of this project is to develop cost effective methods and instrumentation for directly monitoring genotoxic exposure in a variety of natural ecosystems. Direct measurements of the in-situ biological responses associated with genotoxic exposure of sentinel species in the environment circumvents the difficult problem of bioavailability, since measurable molecular endpoints in resident species are a direct reflection of ecologically relevant exposure. The project intends to implement emerging biochip technology for in-situ monitoring of molecular endpoints of genotoxic exposure, including DNA damage-inducible gene expression pathways, in soil and water ecosystems.

BENEFIT: Expanded capabilities for ecotoxicity surveillance, incorporating a comprehensive collection of molecular endpoints associated with military-relevant compounds, would greatly facilitate site characterization, risk assessment and monitoring of the progress of remediation efforts at Department of Defense (DoD) and Department of Energy (DOE) installations. Such capabilities for rapid, multispecies biological endpoint monitoring that is ecologically relevant to cleanup of contaminated sites, should provide a rational basis for reduced cleanup costs, addressing the "how clean is clean?" question. The new technology is expected to enable site closures in a shorter period of time, bringing significant long term cost savings.

TECHNICAL APPROACH & RISK: This project intends to employ novel channel glass biosensor chips containing arrays of DNA probes to characterize and monitor the response of soil microorganisms to exposure to genotoxic agents. The biochip device consists of a glass or silicon dioxide wafer containing miniature patches of densely packed pores of 1-10 μm diam., extending through and perpendicular to the wafer surface. DNA probes can be immobilized within individual porous patches at addressable sites across the wafer, to provide a microscopic array of unique nucleic acid hybridization sites. An array of surface-tethered oligonucleotide probes is called a genosensor. The technical objectives of the project will be achieved via the following specific tasks: (i) fabricate channel glass genosensor arrays containing DNA probes specific to currently known bacterial stress response and DNA damage-inducible genes; (ii) use the "stress response genosensor" to characterize the induction of known stress genes in model soil bacteria exposed in the laboratory to various genotoxic chemicals; (iii) utilize a new genosensor- based oligonucleotide fingerprinting strategy to discover new stress response/DNA damage inducible genes; and

(iv) initiate ecotoxicity surveillance studies with soil and water samples from DOE and DoD sites. The main risks (technical challenges) associated with the project include the requirement to extract intact (undegraded) RNA from environmental samples and the low abundance of soil microorganisms deep below the surface. Feasibility studies will directly address these critical issues in order to define the operational limitations and utility of the approach.

ACCOMPLISHMENTS: In FY98, large sets of candidate gene sequences was collected for potential use in genosensor-based gene expression studies relevant to genotoxic exposure in a variety of species. Sequence database searches (BLAST) have revealed regions of conserved sequence in some of these genes, and oligonucleotide probes were designed to enable detections of transcriptional genotoxicity responses across species. Initial hybridization experiments have been successfully performed on flat glass chips using a bacterial gene sequence known to be induced in response to aromatic toxicant exposure. Channel glass containing pores of several diameters have been fabricated, ethced and characterized by scanning electron microscopy. Methods for extraction of intact DNA and RNA from sediments and soils were evaluated. Inactivation of ribonucleases in soil samples has been demonstrated and various strategies for overcoming the sequestering of RNA by humic acids in soil and silt have been explored. Collaborations have been established to extend genosensor-based genotoxicity response assessment to small animal species found in soil and water environments: the nematode C. elegans and the microarthropod Leptocheirus piumulous. Appropriate gene sequences for these model organisms were selected to permit simultaneous analysis of gene expression responses in microbial and eukaryotic species. The L. plumulosus system can enable direct comparison of established biological methods of genotoxicity monitoring with the genosensor-based molecular endpoint analysis being developed in this SERDP project.

TRANSITION: The project intends to transition through to the Environmental Security Technology Certification Program (ESTCP) for a large scale demonstration. The long term aim of the project is to install and operate genosensor systems at Oak Ridge National Laboratory (ORNL) and the U.S. Army Waterways Experiment Station (WES) for use in assessing ecological effects of genotoxic exposure at DOE and DoD sites.

PROJECT SUMMARY

PROJECT TITLE & ID: Negative Ion Sensors for Real-Time Downhole DNAPLs Detection; CU-1089

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Air Force

LAB: Air Force Research Laboratory - Tyndall Air Force Base, FL

PRINCIPAL INVESTIGATOR: Dr. Gregory Gillispie - Dakota Technologies, Inc.

FY 1999 FUNDS: $288K

OBJECTIVE: The objective of this project is to develop a Site Characterization and Analysis Penetrometer System (SCAPS) probe which can detect, locate, quantify, and determine the subsurface distribution of Dense Non-Aqueous Phase Liquids (DNAPLs) in the soil. Location of the DNAPL sources and reliable estimates of their masses are crucial for cost-effective cleanup. No currently available method can accurately and efficiently define the subsurface distribution of chlorinated solvent DNAPLs.

BENEFIT: Using today's technology, the cost to remediate Department of Defense (DoD) sites alone is estimated at $35B. Annual costs greater than $500K for containment and monitoring a single DNAPL plume are typical. If successful, the sensors developed in this project will provide more cost-effect remediation owing to improved spatial resolution for delineation of DNAPLs source terms, lower sensor acquisition and operating costs, and sensor compatibility with other chemical and physical sensors. Subsidiary benefits include an improved membrane interface for all types of volatile organic compound (VOC) analysis (uphole or downhole) and technology which can be applied to unexploded ordnance (UXO) detection via its chemical signature.

TECHNICAL APPROACH & RISK: The key probe elements are a heated membrane interface and a sensitive, fast-responding downhole detector. Performance objectives have been established as follows: sensor responsiveness to all common organochlorine compounds, vapor limit of detection of 1 ppmv, selectivity better than 5000:1 relative to fuel hydrocarbons, less than 3 second response time, and automatic operation as the probe is advanced by a cone penetrometer or Geoprobe. The research objectives are to characterize the existing Polytetrafluoroethylene (PTFE) membrane's time- and temperature-dependent permeability for chlorinated solvents, fuel hydrocarbons, water, and oxygen; identify, select, and evaluate promising alternative membrane materials; find the material transfer efficiency as a function of distance from the membrane, soil type, temperature, and moisture; and optimize sensor performance, reliability, and ease of operation. Three sensor approaches which exploit the high electronegativity of chlorinated compounds have been identified. They are thermionic ionization sources, a photoemissive electron capture detector (PE-ECD), and a photoemissive ion mobility spectrometer (PE-IMS). The former two will be investigated in this effort. Risk is relatively low because the heated

membrane is already in commercial use and preliminary laboratory data have been acquired for the sensors.

ACCOMPLISHMENTS: In FY98, researchers focused their work on the design and construction of two prototype sensors, both of which are nearing readiness for downhole deployment and field testing. Sensors that can be deployed on direct push probes to detect chlorinated solvents in the form of dense non-aqueous phase liquids (DNAPLs) were developed. The project achieved a prototype thermionic ionization detector (TID) that is fully functional and can be inserted into pipe with 2" outside diameter. A prototype downhole TID was integrated with the membrane interface probe (MIP) that transfers volatile organic compounds from the soil matrix into the gas stream that carries analytes into the reactor cell. The effort to design and build a prototype downhole PID is continuing.

TRANSITION: The project intends to transition through to the Environmental Security Technology Certification Program (ESTCP) for a full scale demonstration/validation in cooperation with Air Force Center for Environmental Excellence (AFCEE) and Environmental Protection Agency (EPA)-Ada, OK. The researchers also have identified the potential for licencing the sensor technology through a third party.

PROJECT SUMMARY

PROJECT TITLE & ID: Integrated Geophysical Detection of DNAPL Source Zones; CU-1090

RESEARCH CATEGORY: 6.3 Advanced Development

LEAD AGENCY: U.S. Air Force

LAB: Air Force Research Laboratory - Tyndall Air Force Base, FL

PRINCIPAL INVESTIGATOR: Dr. Robert Grimm - Blackhawk Geometrics, Inc.

FY 1998 FUNDS: $350K

OBJECTIVE: The objective of this project is to provide cost-effective three-dimensional (3-D) geophysical imaging of the geological control on Dense Non-Aqueous Phase Liquid (DNAPL) distribution and migration at different spatial resolutions and, at the highest available resolution, to directly image DNAPL. Specifically, the project plans to develop and implement computer software for performing joint 3-D high resolution seismic and electrical tomography using surface and borehole measurements.

The first year focus is to conduct a proof-of-concept study that includes: 1) developing laboratory data to support Induced Polarization (IP) tomography measurements of low DNAPL concentrations; and 2) conducting a 2-D tomographic image field test.

BENEFIT: The results of this research development will include computer software, downhole seismic, and electrical instruments, and case histories focused on Department of Defense (DoD)/Department of Energy (DOE) sites. The direct benefit of this integrated package is the unique capability to produce high-resolution 3-D images of geological structures and DNAPLs in the subsurface. Collecting field data and conducting 3-D computer tomographic imaging for monitoring DNAPL migration can be completed in real time. When this approach becomes available, it can facilitate the design of new treatment/remediation technologies. Based on the image of DNAPL distribution and its geological controls, it can also help improve risk assessment and estimate the realistic cost for remediation alternatives. Collecting 3-D surface seismic and electrical data may take 2 days. Downhole seismic and direct current (DC) resistivity measurements may take 1 day. Downhole IP measurements need only a few hours. To install a 2-inch temporary well with cone penetrometer takes a few hours and costs only $2K.

TECHNICAL APPROACH & RISK: The project intends to develop a three-fold approach to characterization of physical heterogeneity controlling DNAPL migration and the ultimate imaging of DNAPL distribution in the subsurface: (1) joint 3-D tomographic inversion of surface seismic refraction and electrical resistivity data to broadly delineate subsurface geology; (2) high-resolution joint 2-D/3-D crosshole tomography using downhole seismic and electrical sources and sensors in permanent 4-inch wells and/or temporary 2-inch boring; (3) utilization of the same downhole electrical sensors to perform IP tomography to image DNAPL with the geological constraints from the above two steps. This three-fold

approach will provide new cost-effective, minimally invasive technologies for 3-D geophysical imaging of DNAPL without producing any secondary waste.

ACCOMPLISHMENTS: In FY98 the Savannah River Site (SRS) was identified as the location of the Phase 2 field experiment. A former settling basin in the A/M area there has extensively leaked DNAPLs. SRS has numerous monitoring wells including many equipped for seismic or electrical monitoring. SRS needs better definition of a near-surface clay facies (the "green clay") to which this project could contribute. Researchers began work on two-dimensional joint tomography of DC electrical resistivity and seismic refraction. This code allows arbitrary surface/downhole geometry and will be the principal analysis tool for the proof-of-concept field experiment. Twenty-two (22) core samples from four wells near the SRS A/M area settling basin were located at the USGS Denver Federal Center and transferred to researchers, who will measure their complex resistivity responses. The project completed the final version of the 2-D joint electrical resistivity and seismic tomography code in mid-September. Synthetic forward and inverse models involving simple anomalies were tested successfully. Researchers measured the complex-resistivity (CR) signatures of 22 core samples from four wells near the SRS A/M area settling basin in their uncontaminated, as-delivered, state. From these one sample was selected that had the largest available mass and was likely to have the best CR response to DNAPL based on the presence of a swelling clay (smectite), as previously determined by XRD. This sample showed a strong amplitude and phase signature of PCE at only 10 parts per billion. Researchers repeated the entire analysis to check the validity of this result. The effect saturates by 1 part per million, i.e., all PCE concentrations above 1 ppm have approximately the same CR signature. While not unprecedented, the high CR-sensitivity of this sample to DNAPL emphasizes that the CR response is highly site specific.

TRANSITION: Providing a successful initial proof-of-concept study, the project has a transition plan that includes the possible integration with existing systems such as SCAPS to apply the technology developed. Other potential users of the three-dimensional geophysical imaging of DNAPL distribution and migration include: the Air Force Research Lab, Sandia National Lab, and Lawrence Berkeley National Lab.

PROJECT SUMMARY

PROJECT TITLE & ID: Innovative Seismic System for Buried Unexploded Ordnance Detection and Classification; CU-1091

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Army

LAB: Waterways Experiment Station - Vicksburg, MS

PRINCIPAL INVESTIGATOR: Mr. Peter Krumhansl - BBN Systems and Technologies

FY 1999 FUNDS: $667K

OBJECTIVE: The objective of this effort is to investigate and develop a new Seismic Ordnance Detection System (SODS), which can improve the discrimination of unexploded ordnance (UXO) from clutter and thus reduce the number of excavations required during cleanup.

BENEFIT: The project intends to provide to SERDP: 1) a fully developed seismic ordnance detection system (SODS) that will significantly improve the accuracy of UXO site characterization and reduce excavations and cleanup costs; 2) a SODS that will provide UXO detection and classification capabilities in environments where other sensors perform poorly; and, 3) a SODS that will detect non-metallic ordnance and other buried wastes or structures.

TECHNICAL APPROACH & RISK: The new seismic sensor will sense the mechanical properties of buried objects rather than their magnetic or electrical properties. The SODS system will operate in a manner similar to an active sonar system, with a mobile seismic array which sends broadband vibrational energy into the ground. These waves when they encounter an object with anomalous mechanical properties cause the object to rotate, translate, and to "ring," scattering energy back to the surface. These echoes will be received by an array of geophones and digitally recorded. The received signals are beamformed to locate the objects and to analyze the characteristic echo from the object. These characteristic echoes when used in conjunction with the magnetic and electrical response will more efficiently differentiate UXO from inert objects. After development and characterization of the performance of SODS, it can be used as one of a suite of sensors that can be tailored to specific site conditions and UXO types. This will significantly reduce survey and cleanup costs, especially in areas with high metal clutter or environmental degradation of the performance of other sensors.

The technical approach for the investigation and development of the SODS consists of three phases: 1) performance of an initial feasibility study to analyze the practicality of seismic UXO detection using short wavelength shear waves; 2) development of a proof-of-concept SODS for testing; and, 3) evaluation of the proof-of-concept SODS in controlled testing. The system simulation of SODS will be based on computer modeling and field measurements of seismic wave propagation and noise. The second phase will

utilize seismic sources and receivers that provide greater bandwidth, increased source level, and better earth coupling than are commercially available while engineering a practical mobile array of seismic transducers that can be used to efficiently collect seismic data. The third phase will include refining of the proof-of-concept system through diagnostic tests and analyzing detections of UXO culminating in an initial evaluation of SODS in multi-sensor tests and an analysis of false alarm reduction using the seismic data in a sensor fusion process.

ACCOMPLISHMENTS: The primary areas of progress during FY98 for the development of the Seismic Ordnance Detection System include: 1) Seismic Field Testing; 2) Analysis of Seismic Propagation and Noise Measurements; 3) Testing of Seismic Sources and Receivers; 4 Analysis of Buried 155mm Shell Seismic Response; 5) Development of Seismic System Simulation Software; and 6) Analysis of Potential System Resolution.

The first set of field tests to provide a basis for system performance analysis and modeling was performed in July, 1998. The goals of the field effort were: 1) To measure seismic wave propagation, noise and reverberation; 2) To assess seismic bandwidth of sources and receivers; 3) To test in - situ seismic response of a 155 mm artillery shell; and, 4) Assess 2-D array noise and imaging capability. These tests were performed at a site along the Souhegan River in Southern New Hampshire in a relatively simple soil composed of sand and clay with no rocks. The seismic velocities were measured by placing geophones in lines along the surface and placing geophones in holes in the ground. Seismic sources were used at different locations relative to the arrays of geophones to permit analysis of different wavetypes. The researchers acquired a 155mm shell from the UXOCOE office, which was filled with paraffin, and instrumented this shell by attaching 4 accelerometers on the top, sides, and tail. The shell was then buried in the ground at a depth of 1 meter. The buried shell was excited from the surface with two broadband seismic sources, the sliding hammer and the small vibrator. The sources were placed at different relative locations to the buried shell to ensonify the shell from different angles. Time series signals were recorded for each source. Further data collection and analysis activities will progress into FY99..

TRANSITION: The project intends to transition through to the Environmental Security Technology Certification Program (ESTCP) to develop a fieldable Seismic Ordnance Detection System prototype.

PROJECT SUMMARY

PROJECT TITLE & ID: Model-Based Data Fusion and Discrimination of UXO in Magnetometry and EM Surveys; CU-1092

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Navy

LAB: Naval Research Laboratory - Washington, D.C.

PRINCIPAL INVESTIGATOR: Dr. J.R. McDonald

FY 1999 FUNDS: $515K

OBJECTIVE: The objective of this project is the development of data fusion techniques for the best available existing sensor suites, to better allow discrimination between intact ordnance and the typical clutter associated with target and bombing ranges. Specifically, Naval Research Laboratory (NRL) intends to develop software techniques to allow discrimination of intact ordnance from Ordnance Explosive Wastes (OEW) using arrays of full-field magnetometers and time-domain electromagnetic sensors as the primary detection tools. These goals will be accomplished by developing new software for target identification, physical modeling, and probablilistic classification that uses the sensor data sets jointly. NRL's Multi-Sensor Towed Array Detector System (MTADS) will be the primary platform for which the software will be designed, although the work is applicable to any magnetic and electromagnetic array measurements and some aspects of the development are relevant to other types of sensor data.

BENEFIT: When integrated into an operational unexploded ordnance (UXO) survey system such as MTADS, this data analysis system will reduce target analysis time by up to 50 percent. Location information, including position, size and depth, is expected to also be mildly improved. The major benefit of this analysis will be a significantly improved ability to differentiate UXO from OEW and other clutter. An improvement in false alarm levels of a factor of two will reduce ordnance remediation costs by 50 percent at most sites. The probabilistic approach used by the network classifier will provide statistical information that will be important for Quality Assurance/Quality Control (QA/QC) site analysis and for risk-based cost benefit analyses.

TECHNICAL APPROACH & RISK: The key goals of UXO classification and OEW discrimination can best be achieved by a thorough consideration of the fundamental physics of sensors and a development of classification schemes, based on physical understanding, that provide quantitative confidence levels. Therefore, a favored approach is model-based rather than based on raw data. The latter approach performs classification directly from sensor data, whereas this approach performs a joint transform of data to derive physical parameters (position, depth, orientation) allowing the classification to be based primarily on shape information and the intrinsic variables. Initially, raw magnetometry and EM survey data that have been preprocessed (to integrate navigation and sensor data) and mapped onto a two dimensional grid will be

automatically processed using principal component analysis to isolate targets with common features in the multiple data sets. Based upon initial studies with MTADS data from Twentynine Palms and the Badlands Bombing Range, the researchers expect that using this data based approach, 70-90 percent of targets can be automatically selected and analyzed. Following the automatic target selection process, model-based quantitative magnetic and EM routines will be used to solve the inverse problem for target position, depth, shape, and orientation. Then a probabilistic classifier (Bayesian or neural net) will model the output to identify likely UXO type and distinguish OEW or other clutter. Finally, an analyst, (as a backup to the automatic target picker) will work interactively with the individual graphical images, to pick targets which are not common to the magnetometer and EM data sets (or for which the automatic target picker solution was not accepted) for subsequent analysis by the physics-based target fitting routines.

ACCOMPLISHMENTS: The project made progress during FY98 along various paths. Successful fusion of seven data sets from Badlands and Bloom Point sites were demonstrated using PCA. The first principal component describes the fused data sets when covariance or correlation matrices with standardization are used. In addition, digital filtering was investigated. The key to this kind of digital filtering is choosing the appropriate filter function. Two linear filter functions, Gaussian and Laplacian of Gaussian (LoG) have been investigated. For both types of filters, various widths and window sizes were studied to characterize the performance of the filters on MTADS images. Features are enhanced using filtering techniques. PCA analysis following digital filtering provides sensor fusion and enhanced images.

TRANSITION: The project has a transition plan that includes: 1) integration of the new analysis system into the MTADS for evaluation; 2) transition of the project to the Environmental Security Technology Certification Program (ESTCP) for demonstration/validation at a live-fire range; and, 3) eventual transition of the current MTADS to the commercial sector.

PROJECT SUMMARY

PROJECT TITLE & ID: In-Situ Clay Formation: A New Technology for Stable Containment Barriers; CU-1093

RESEARCH CATEGORY: 6.1 Basic Research

LEAD AGENCY: U.S. Department of Energy

LAB: Sandia National Laboratory - Albuquerque, NM

PRINCIPAL INVESTIGATOR: Dr. J. David Betsill

FY 1999 FUNDS: $330K

OBJECTIVE: A new type of containment barrier with a potentially broader range of environmental stability and longevity could result in significant cost-savings to the Department of Defense (DoD) and Department of Energy (DOE). This project intends to precipitate clays in-situ in porous geologic materials by building on the technologies that exist for colloidal or gel stabilization. Unlike colloidal or gel barriers, however, a precipitated-clay barrier does not require saturated conditions to be functional. Thus, it can be emplaced without loss of performance in the vadose zone as well as areas with fluctuating water tables. Clays have the advantage of being geologically compatible with the near-surface environment and naturally sorptive for a range of contaminants. The precipitation of clays in-situ in soils and sediments should result in (1) reduced permeability and hydraulic conductivity and (2) increased mechanical stability through cementation of soil particles. By analogy with natural diagenesis in sedimentary rocks, the researchers intend to engineer "artificial" lithification in soils and sediments. Unlike natural diagenesis, however, the time-scale for clay growth will be accelerated greatly from more than tens of thousands of years down to a few weeks.

BENEFIT: The results from this project will yield a new barrier technology that potentially has a broader range of mechanical and chemical stability and therefore, can be applied in a broader range of environments ranging from arid to humid, and to specific contaminants, ranging from Dense Non-Aqueous Phase Liquids (DNAPLs) to metals. DoD and DOE cleanup sites are located in a wide range of environments across the country and have a range of contaminants. The new barrier technology should also possess greater longevity requiring less maintenance over the longterm and less risk of remediation due to barrier failure or leakage. Total cleanup costs to the DoD and DOE should be substantially reduced due to the longer lifetime of the barrier. Once developed, it is anticipated that the implementation cost of the new barrier technology should be on the order of the least expensive chemical grouting technologies currently available.

TECHNICAL APPROACH & RISK: The technical approach is multidisciplinary and involves plans to: (1) confirm published results suggesting that clays can be precipitated in a few weeks to months from aqueous gels; (2) design an optimal gel composition that will maximize clay yield and crystallization rate,

experiments; and, (4) test the method in a field experiment. The critical key step in developing the new barrier technology will be to successfully optimize the formation of clays from aqueous gels under ambient conditions. Therefore the first year of the project will be focused on this step. However, we will also initiate the laboratory experiments and measurements (flow properties and mechanical stability) in order to address technical details that may arise with the materials or experimental design. Gel composition will be designed using approaches taken from the literature involving reactions and additives known to accelerate clay formation. Emphasis will be placed on characterizing the clay with respect to quantity, composition, and crystallinity. Emplacement of gels in laboratory tests will emulate field technologies such as permeation and jet grouting, and soil-mixing.

ACCOMPLISHMENTS: In FY98, the University of Colorado group successfully synthesized Al-bearing hydrotalcites, kaolinite clay, and meso-aluminosilicates at ambient temperature in the laboratory within 15 to 42 days. The synthesis of kaolinite grains a few tenths of microns in diameter was conducted using aqueous solutions containing dissolved aluminum, silicon, and fulvic acid (Suwannee River fulvic acid, a standard from the International Humic Substances Society). Experiments were underway to determine factors that control the kinetics of kaolinite precipitation. Researchers also investigated other sources of fulvic acid as catalysts for kaolinite formation and further characterizing the other precipitated materials, especially with respect to their stability in the environment. A manuscript describing the nucleation of 2:1 layer clay in the surface of quartz grains was submitted on Oct. 22 to the American Mineralogist, the journal of the Mineralogical Society of America. The title is "Evidence for the formation of trioctahedral clay upon sorption of CO_2+ on quartz".

TRANSITION: The project has a transition plan that includes: 1) full-scale demonstration of the clay formation technology at a DoD site; 2) pursuit of cooperation with industry and consortia (i.e., Remediation Technologies Development Forum); and 3) direct sharing of information on the methodology to DoD and DOE installation managers.

PROJECT SUMMARY

PROJECT TITLE & ID: Environmental Impacts to the Chemical Signature Emanating from Buried UXO; CU-1094

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Department of Energy

LAB: Sandia National Laboratory - Albuquerque, NM

PRINCIPAL INVESTIGATOR: Mr. James Phelan

FY 1999 FUNDS: $188K

OBJECTIVE: The objective of this project is to develop a validated subsurface transport model that can be used to predict the spatial and phase specific concentration of chemical signature molecules derived from shallow unexploded ordnance (UXO) under the influence of specific environmental conditions. Other government programs are developing chemical detector platforms that can provide a separate unique signal to classify subsurface objects identified with existing geophysical systems. It is estimated that eleven million acres of land needs assessment to identify subsurface UXO - with costs estimated to be about $1.4M/acre. The ranges where UXO can be found is distributed throughout the country where environmental conditions vary significantly. It is the hypothesis of this project that these environmental conditions will have a significant impact on the transport of chemical signature molecules from subsurface UXO to the surface before presentation to a chemical detector system. If through this systems analysis, one can show the ranges and/or combinations of environmental parameters that improve the transport of chemical signature molecules to the chemical detector system, and conversely, those that constrain this movement, end-users seeking to will be better positioned to understand the merits and limitations when looking to deploy the chemical detector technology.

BENEFIT: This project will provide Department of Defense (DoD) with a new tool to assess the functionality of chemical detector platforms in service to classify shallow UXO from non-UXO. Use of the model, simulations, and systems analysis will improve the decisions made on the utility of chemical detector platforms in a variety of environmental conditions that are expected to have an important role in the transport of chemical signature molecules from shallow UXO. If chemical detector platforms can meet the performance requirements for many application sites, a substantial savings can be expected in reducing the number of non-UXO items treated as UXO during range cleanup activities.

TECHNICAL APPROACH & RISK: The first task is to perform a sensitivity analysis of known input parameters in a one-dimensional analytical contaminant transport model, expand this model to assess two-dimensions to explore the surface area footprint from buried UXO, modify an existing numerical simulation code (T2VOC) (precipitation/evaporation, temperature cycling, liquid diffusion) for use as the complete systems analysis tool. Inverse modeling will be used to assess input parameter sensitivity and

as a tool for the design of laboratory validation experiments in task three. Task two involves the measurement of specific transport parameters currently not available in the literature for explosive signature molecules. These include temperature dependent water solubility, vapor-solid sorption as a function of soil moisture content and source-term emission rates. Task three will be a laboratory validation study that will confirm the most critical parameters included in the simulation model. Task four will utilize this validated model to assess the impacts of environmental conditions on the transport of chemical signature molecules from shallow UXO and support end-user queries on the utility of chemical sensor platforms for the classification stage in the identification of true unexploded ordnance.

ACCOMPLISHMENTS: The project made progress during FY98 along three distinct Tasks:
Model Development/Utilization - The 1-D screening model has been adapted for a 2-D analysis to evaluate the surface expression of a subsurface buried UXO. The results indicated that for a shallow buried object, most environmental conditions will produce a surface expression directly above the buried object. Long travel times will produce more spreading at the ground surface, but the concentrations gradients are very steep. The phase partitioning model has been used in a Monte Carlo simulation to evaluate the probability of detection for selected soil environmental conditions and a minimum detectable mass typical of laboratory grade electron capture detectors. This method was very effective in screening the minimum soil concentration needed for successful vapor sniffing at the ground surface. This data was very helpful for technology developers by defining performance targets.

Lab-Scale Experiments - The experimental design was completed. The columns used time domain reflectometry for soil measurements in discrete layers through the height of the soil column. Soil gas sampling ports were included in the column sides and are suitable for solid phase micro extraction sampling technology. The columns will be about 18 inches in diameter and about 24 inches tall.

Ordnance Source Term - Planning for the tests began. Ten each of 105 mm artillery, 60 mm and 81 mm mortars were acquired. Water baths were used for the source flux experiments, with samples obtained daily for three weeks. Ordnance items had dummy fuzes installed and were shot at an average velocity into soil berms. Ordnance was then collected and tested as in the pre-test. Soil samples were collected surrounding live UXO to evaluate the in-situ chemical signature residues. The Bonnevile Range was considered a location to collect these samples as they have a large number of 105 mm artillery UXO.

TRANSITION: The project has a transition plan that includes: 1) sharing of Performance Targets directly with developers of commercial chemical detector systems; 2) making available operational strategy information to end-users; and, 3) pursuing advancement of the chemical detector platform through a demonstration/validation field testing program, such as the Environmental Security Technology Certification Program (ESTCP) or the U.S. Army Night Vision Lab.

PROJECT SUMMARY

PROJECT TITLE & ID: Assessment and Prediction of Biostabilization of Polycyclic Aromatic Hydrocarbons (PAH) in Sediments; CU-1095

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Army

LAB: Waterways Experiment Station - Vicksburg, MS

PRINCIPAL INVESTIGATOR: Mr. Jeffrey W. Talley

FY 1999 FUNDS: $500K

OBJECTIVE: The objectives of this research are to identify those factors affecting biostablization of Polycyclic Aromatic Hydrocarbons (PAHs) in sediments and to develop the technical basis for enhancing natural recovery processes for the biotreatment of PAHs in dredged material. The key questions to be addressed in this research are: (1) Where exactly at the microscopic scale do PAHs reside on aged sediments?; (2) How are the microscopic-scale locations of PAHs on sediments dependent on sorbent carbon location and type?; (3) What are the distribution of binding activation energies for desorption of PAHs from sediment particles, and how does this correlate with information on PAH association with sorbent carbon type?; (4) How does the effectiveness of bioslurry treatment of dredged sediments depend on the locations and associations of PAHs with sorbent organic matter and distributions of binding activation energies with respect to removal of specific compounds, the fraction of labile and resistant PAHs, and the toxicity of residual PAHs?; and (5) How may knowledge of the association of PAHs with sorbent carbon type and location, and distribution of binding activation energies, be used to assess and predict the overall performance of bioslurry processes for biostablization of PAHs? This research will assess the fundamental character of the binding of PAHs at the microscopic scale in parallel with bioslurry treatment and ecotoxicological testing, to show how the nature of PAH association with sediments related to biostablization, achievable treatment endpoints, toxicity, and bioavailability. The work will explore mechanisms controlling PAH sequestration using novel spectroscopic techniques to examine at the microscale the distributions and associations, and binding energies of PAHs in sediments.

BENEFIT: The potential benefits of this research include: reduced treatment costs, improved evaluation and design for clean-up technologies, greater regulatory and public acceptance of biostablization, increase in the reuse/recovery opportunities for treated contaminated dredged materials, and potential application for in-capped sediments.

TECHNICAL APPROACH & RISK: The project's overall goal is to develop micro-scale characterization of PAH homolog distributions in sediment, and to use this information to provide more direct evidence of PAH associations with geosorbents for the construction of mechanistically-based conceptual models to aid interpretation of bioslurry treatment efficiency and toxicity of treated and untreated material. The novel aspect of this research is the use of unique, complementary spectroscopic

techniques to assess where and how PAHs are bound to sediments. The technical approach for the first year is: 1) investigate the utility of microprobe two-step laser desorption/laser ionization mass spectrometry uL2MS, for direct observation of PAHs on aged laboratory and field soil/sediment particles at the microscopic scale, i.e., 40 um or less; 2) employ the uL2MS method to examine lateral and criss sectional variations of PAH homolog distributions on sediments; 3) compare the surface and sectional amounts of PAH homologs obtained by uL2MS with results from conventional whole sample extraction and Gas Chromatography/Mass Spectrometry (GC/MS) or Gas Chromatography/Free Induction Decay (GC/FID) analyses; and, 4) determine the distribution of microorganisms on sediment particles, and the competence of these organisms to degrade PAHs.

ACCOMPLISHMENTS: Work during FY98 involved analysis of sediment particle surfaces for sediment organic matter location using FTIR microspectroscopy. Significant advances were made in identifying organic matter presence on sediments and their aliphatic or aromatic nature. Additionally, locations of sediment organic matter were correlated with the location and abundance of PAHs on sediments. Findings from these studies are being put together as a paper for submission to a peer-reviewed journal. Cross sectional PAH concentrations were determined for sectioned particles from Milwaukee and GRI sediments at Stanford. PAH concentrations were found to be significantly higher on the outside compared to that of the interior of Milwaukee sediment particles. However, the PAH concentrations within GRI sediment were not significantly different from the exterior of the particles. This is explained by the nature of the GRI sediment, which appears to be an agglomerate of smaller particles. For each of the smaller particles trapped in the larger GRI sediment agglomerate a dramatic reduction of PAH concentration was observed from the edge of a particle to the middle which corresponds to the exterior and interior. The thermal programmed desorption (TPD) MS instrument has been procured and configured at WES. Initial results using standard materials and Milwaukee sediment have been obtained. Work continues at NRL on the development of a PAH degrader in which the gene for the production of green fluorescent protein (GFP) is integrated with the regulatory system of the PAH degradation pathway. Construction of a plasmid with a phenanthrene promoter placed up stream of the GFL gene has been completed using E. coli as a vector. The plasmid was constructed with an appropriate antibiotic resistance marker to allow selection using a broad host range vector that would express in the P. putida strain. The phenanthrene promoter-GFP construct has been successively transferred into the P. putida and experiments are being conducted to determine if the current construct will express properly. If it does, further experiments will be conducted to characterize the growth conditions for optimal expression. If there is no expression, the construct will be checked by sequence analysis to determine that no errors occurred during the construction process.

TRANSITION: The project has a transition plan that includes dissemination of results through established scientific communications channels, as well as proposed partnering efforts with the Army Research Office and the Gas Research Institute.

PROJECT SUMMARY

PROJECT TITLE & ID: Processing Techniques for Discrimination between Buried Unexploded Ordnance and Clutter Using Multisensor Array Data; CU-1121

RESEARCH CATEGORY: 6.1 Basic Research

COTR AGENCY: U.S. Army

LAB: Waterways Experiment Station - Vicksburg, MS

PRINCIPAL INVESTIGATOR: Dr. Thomas Bell

FY 1999 FUNDS: $402K

OBJECTIVE: The objective of this project is to develop a reliable technique for discriminating between buried UXO and clutter using multisensor electromagnetic induction sensor array data. The effort builds on existing research which exploits differences in shape between ordnance and clutter to include the effects of other distinctive properties of ordnance items (fuze bodies, driving bands, fin assemblies, etc.).

BENEFIT: The product of this research is primarily processing algorithms and procedures for using existing sensor technology within the less than 100 KHz domain.

TECHNICAL APPROACH & RISK: Specifically, the project intends to perform tests in the less than 100 KHz domain. The effort will develop: 1) models for the ordnance signature and its constituent parts; 2) procedures for determining target characteristics from multisensor data using the signature models; and 3) decision rules for discriminating between buried UXO and clutter.

ACCOMPLISHMENTS: This is a FY 1999 New Start.

TRANSITION: Primary products are ability to optimize EMI sensor array configuration and effective processing algorithms for EMI data. These may be directly transitioned to modify the MTADS platform and data analysis system. Introduce measurement techniques and processing algorithms in commercial survey work. The research effort also entails direct insolvent with the user community.

PROJECT SUMMARY

PROJECT TITLE & ID: UXO Discrimination by Mid-Frequency Electromagnetic Induction; CU-1122

RESEARCH CATEGORY: 6.1 Basic Research

LEAD AGENCY: U.S. Army

LAB: Cold Regions Research and Engineering Laboratory - Hanover, VT

PRINCIPAL INVESTIGATOR: Dr. Kevin O'Neill

FY 1999 FUNDS: $307K

OBJECTIVE: Perform basic research on sensor development, sensor utility, and signature possibilities in the uncharted 25 kHz - 300 kHz (MF-EMI) electromagnetic frequency band, for induction sensing of buried UXO. The goal is to provide enhanced discrimination of ordnance from non-ordnance, and thereby reduce false alarm rates during field surveying. This will be accomplished by innovative instrumentation development in the MF-EMI band, in tandem with new modeling work.

BENEFIT: This work builds directly on recent progress in innovative EMI signature identification in the lower frequency EMI range (100 Hz - 25 kHz) and thereby amplifies its impact. As basic research it will not provide immediate answers, but is directed towards aiding in: 1) Substantial reduction of the false alarm rate in UXO field surveying; 2) Cheaper remediation of UXO hazard sites; 3) Faster and safer surveying of potential hazard sites; and, 4) Computational and modeling tool development for wide range of related electromagnetic applications.

TECHNICAL APPROACH & RISK: Technical objectives include: 1) Perform lab measurements of soil electrical properties, including seasonal effects, for samples relevant to UXO sites in order to quantify expected subsurface signal loss rates; 2) Extend and verify suite of computer programs to achieve rigorous 3-D solution of the physics of response by non-idealized UXO and non-UXO targets in realistic environments in this frequency range; 3) Produce high fidelity simulations in time, space, and frequency domains of the response by a wide range of specific UXO morphologies and dispositions, and by common non-UXO targets (fragment clusters, tin cans, open shapes, etc.) in realistic environments; 4) Obtain measured induction responses for array of UXO and non-UXO targets, using technology to be developed and exploiting existing data bases where possible; and, 5) Use all of the above to identify distinctive UXO signature behaviors, and their discernibility relative to the environment, for combination with those being obtained in frequency ranges both above and below 25 KHz - 300 KHz.

ACCOMPLISHMENTS: This is a FY 1999 New Start.

TRANSITION: The project intends to transition through to the Environmental Security Technology Certification Program (ESTCP). Also, integration in basic research effort of industrial partner with wide experience in developing innovative instruments, followed by field testing, application, and ultimately commercial distribution.

PROJECT SUMMARY

PROJECT TITLE & ID: Statistical Signal Processing with Physics-Based Models: Multi-sensor UXO Detection and Identification; CU-1123

RESEARCH CATEGORY: 6.2 Applied Research

COTR AGENCY: U.S. Army

LAB: Waterways Experiment Station - Vicksburg, MS

PRINCIPAL INVESTIGATOR: Dr. Leslie M. Collins

FY 1999 FUNDS: $283K

OBJECTIVE: Several sensor modalities are currently being explored for the detection and identification of surface and buried UXO. These include electromagnetic induction (EMI), magnetometers, radar, and seismic sensors. These sensors experience little difficulty detecting the UXO, thus detection does not create the bottleneck that results in the high cost of remediating sites. The primary contributor to the costs and time associated with remediating a UXO contaminated site is the high false-alarm rate associated with each of the sensors when operated individually. In this project, we will investigate the phenomenological aspects of the UXO detection, location, and discrimination problem using EMI, radar, seismic, and magnetometer sensors. The fundamental insight garnered by characterizing the underlying physics will be transitioned into high-performance sensor fusion and signal-processing algorithms for enhanced detection, location, and discrimination of buried UXO under a wide range of environmental conditions.

BENEFIT: The goal of this project is to develop algorithms that substantially reduce false alarm rates associated with individual sensors, and that optimally combine information across sensors to further reduce the false alarm rate. Such reductions would dramatically decrease the time required to remediate FUDS and BRAC sites, thus decreasing the associated costs. One of the principal reasons for organizing cooperative agreements with ARL, NRL, and BBN is to assure the models and algorithms developed under the proposed research are transitioned as quickly as possible to the users in the field. It is felt that the collaborative relations will allow us to tailor our developments such that they are of use to practical systems. Moreover, these organizations, which are responsible for hardware design and measurement campaigns, will gain insight from our phenomenological models to assure that the systems are designed and deployed in the most salutary fashion. After each milestone is completed, the attendant software will be released to SERDP for all SERDP contractors to use.

TECHNICAL APPROACH & RISK: The technical approach will employ synergistic research activities in modeling, signal processing, and sensor fusion. The researchers will perform phenomenological modeling of wave propagation and scattering for ultra-wideband (UWB) radar, seismic, and EMI sensors. The phenomenological studies will be performed in collaboration with SERDP-supported sensor-development programs underway in these areas (at NRL, ARL, and BBN). The previously

developed models will be extended to allow arbitrary numbers of soil layers, arbitrary target shape and orientation, and to accurately account for all interactions. The use of these models will quantify the target types, depths, and soil conditions for which radar is an appropriate sensor.

These models of the wave physics, coupled with models of target, clutter, and environmental uncertainties, will be incorporated into a statistical signal processing framework, thus novel, state-of-the-art optimal detection and identification algorithms will be developed for each sensor. Bayesian algorithms, which provide the optimal solution to detection and identification problems, will be investigated along with an algorithm based on a Hidden Markov Model formulation which is specifically suited for classification using data from multiple aspect angles. Finally, the researchers will develop sensor-fusion techniques that simultaneously exploit the richness and diversity of the phenomenology underlying multiple sensor modalities. Again, both Bayesian and Hidden Markov Model algorithms will be investigated. In all cases, the algorithms that are developed will be tested on data collected using sensor systems also under SERDP support, such as the BBN seismic sensor, NRL's MTADS system, the ARL Boom-SAR, and Geophex's GEM-3 EMI sensor.

ACCOMPLISHMENTS: This is a FY 1999 New Start.

TRANSITION: The project intends to transition cooperative developments. These include organized cooperative agreements with ARL, NRL, and BBN.

PROJECT SUMMARY

PROJECT TITLE & ID: An Innovative Passive Barrier System Using Membrane-Delivered Hydrogen Gas for the Bioremediation of Chlorinated Aliphatic Compounds; CU-1124

RESEARCH CATEGORY: 6.2 Applied Research

COTR AGENCY: U.S. Air Force

LAB: Air Force Center for Environmental Excellence - Brooks AFB, TX

PRINCIPAL INVESTIGATOR: Dr. Michael Semmens

FY 1999 FUNDS: $317K

OBJECTIVE: The objective of this project is to examine the gas transfer behavior and performance of hollow fiber membrane curtains that are installed as passive barriers. The proposed research will assess the suitability and effectiveness of the membrane for delivering hydrogen (H2) to accelerate the in situ remediation of chlorinated organic compounds like trichloroethene (C2HCl3) and perchloroethene (C2Cl4).

BENEFIT: This proposal specifically responds to a SERDP statement of need (CUSON-99-03) with the overall goal of developing an innovative passive barrier remediation technology that will reduce the costs, risks, and time required for contaminated site cleanup. The proposed research will characterize the performance of a novel passive barrier that relies on the use of an innovative membrane technology for the controlled dissolution of H2. The research will employ special woven hollow-fiber membranes for the passive dissolution of H2 in order to accelerate the in situ bioremediation of groundwater contaminated with chlorinated compounds. The hollow fiber membrane curtain can act as both a gas supply and a biofilm support. These modules can be designed to provide a large surface area for gas transfer while presenting minimal hydraulic resistance to flow. Modules of woven fibers can be installed using trench technologies and placed to create a flow-through passive barrier that is oriented normally to the direction of groundwater flow. In this way the membrane curtain provides passive gasification of the groundwater flow without the need for pumped wells, gates, or other forms of flow modification.

Passive barrier remediation systems are an attractive treatment option for the transformation of contaminated groundwater. However, problems exist concerning the use of elemental iron barriers. H2 appears to be an effective electron donor for the biodegradation of halogenated aliphatics when it is sufficiently bioavailable. However, it is difficult to provide sufficient H2 to organisms due to its low solubility. Gas permeable membranes, used as a passive treatment barrier, could be used to provide H2 as an electron donor for in situ bioremediation. This method of H2 delivery would be expected to provide controlled levels of bioavailable H2 that should provide the same benefits as cathodically derived H2, without the associated problems.

This SERDP funded research will prove the technical feasibility of using membranes for H2 delivery to contaminated groundwaters. In addition, the project will yield the engineering data required to complete a cost analysis and transition the membrane-module remediation system technology into field scale application.

Preliminary analysis suggests that passive barrier membranes will provide a cheaper remediation technology than passive barriers of elemental iron. In addition, the membrane technology is expected to have less of an adverse impact on groundwater quality. Cost estimates and the cost advantage of this technology will be estimated in the first year of the project.

TECHNICAL APPROACH & RISK: The proposed research will investigate the behavior of the membranes in a systematic way to determine what factors control the overall remediation process. These tasks include: 1) Gas Dissolution Behavior of Membranes, 2) Impact of Gas Composition Changes and Condensation, 3) Impact of Biofilm Growth on Gas Transfer 4) Evaluation of Solvent Transformation 5) Mathematical Model Development, and 6) Pilot Reactor Studies. The risks involved in this process include: 1) The membranes may not transfer H2 fast enough when the groundwater is moving so slowly, 2)The membranes may foul and their gas transfer performance may be lost, 3) Methanogens may exploit the high local H2 pressure and grow preferentially. If this happens, most of the H2 will be used to form methane gas which could accumulate locally and impede effective bioremediation by halorespirers, 4)The use of H2 raises safety issues. In addition, the accumulation of locally high concentrations of methane are also of concern, since both H2 and methane are flammable gases, 5) The accumulation of excessive biomass locally could cause a loss of permeability and a poor flow distribution through the affected site, and 6) The installation process may damage the membranes and render them ineffective.

ACCOMPLISHMENTS: This is a FY 1999 New Start.

TRANSITION: The project intends to transition to the user community including, Porous Media, Minntech Corp. and Membran Corp. The project intends to select a site within DoD for field demonstration/validation.

PROJECT SUMMARY

PROJECT TITLE & ID: Influence of Groundwater Constituents on Longevity of Iron-Based Permeable Barriers; CU-1125

RESEARCH CATEGORY: 6.2 Applied Research

COTR AGENCY: U.S. Navy

LAB: NFESC - Port Hueneme, CA

PRINCIPAL INVESTIGATOR: Dr. A. Lynn Roberts - Johns Hopkins University

FY 1999 FUNDS: $350K

OBJECTIVE: This project investigates factors which may limit the longevity of iron-based permeable barriers used for in situ treatment of organic- or metal-contaminated groundwaters by examining the long-term performance of laboratory columns packed with a porous medium containing zero-valent metal solids and through which simulated groundwater of differing compositions is passed, by examining the influence of eluent composition and time on the evolving composition of the solid surfaces, and by monitoring the electrochemical characterization of the surfaces after varying times of exposure. Particular emphasis is placed on developing new approaches for "real-time" monitoring of changes in system performance through a novel electrochemical probe that can be installed in situ in pilot- or full-scale applications.

BENEFIT: The major output of this work will be basic research: first and foremost, an improved understanding of the impact of the aqueous chemistry on the longevity of iron, both from the perspective of "aging" and also from clogging. This project should provide a fundamental understanding of important issues dictating barrier longevity, allowing improved assessment of life cycle costs. We will use our results to design guidelines that outline reasonable "safety factors" concerning assumed permeable reactive barrier residence times as a function of design life of the barrier. Overall, the results of this work will allow better evaluation of the tradeoff between construction costs (e.g., barrier thickness) and system longevity. The understanding and tools developed through this effort will be directly relevant to users who apply permeable iron-barrier technology for treatment of chlorinated solvents or explosives at DoD/DOE sites. The electrochemical probe to be developed through this work has considerable promise for rapid implementation as a tool for monitoring reactivity changes in full-scale applications.

TECHNICAL APPROACH & RISK: The principal technical objectives are to evaluate the impact of groundwater composition on the long-term performance of zero-valent iron (Fe) barriers and to develop a prototypic electrochemical probe for monitoring reactivity changes at either the field or laboratory scale. We intend to conduct an integrated research program to meet the following specific objectives:
(1) to understand the effects of groundwater chemistry on long-term barrier performance, including delineation of the impacts of chemical reactivity changes and alterations in transport properties;

(2) to develop an electrochemical probe that can be used to continuously assess the ongoing performance of a reactive barrier, either in laboratory columns or in situ in the field;
(3) to develop a fundamental understanding of the causes of alterations in reactivity through studying its relationship to the changing composition of the iron surface;
(4) to incorporate the results of our studies into a set of guidelines that can be used to predict the impact of the above factors on reactive barrier performance.

Arrangements were made with USAF Research Laboratory to interface the project's studies with an ongoing SERDP-sponsored project entitled "Permeable Barrier Demonstration at Area 5, Dover AFB". This project involves the installation of two iron-based reactive barriers within an existing plume of chlorinated solvent contaminants at Dover AFB, DE. Plans are in place to obtain core samples of the reactive media from different locations within the barriers near the end of the project, and to analyze segments via scanning electron microscopy to obtain information pertinent to morphological changes, and x-ray diffractometry to identify well-defined crystalline mineral phases that might be precipitated.

ACCOMPLISHMENTS: This is a FY 1999 New Start.

TRANSITION: The project intends to transition through to the Environmental Security Technology Certification Program (ESTCP), USAF Research Laboratory, Air Force Center for Environmental Excellence, EnviroMetal Technologies, Inc., and Remediation Technologies and Development Forum.

PROJECT SUMMARY

PROJECT TITLE & ID: Development of Effective Aerobic Cometabolic Systems for the In-Situ Transformation of Problematic Chlorinated Solvent Mixtures; CU-1127

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Air Force

LAB: AFRL - Tyndall AFB, FL

PRINCIPAL INVESTIGATOR: Ms. Alison Lightner

FY 1999 FUNDS: $370K

OBJECTIVE: The projects objective is to remediate TCE and other chlorinated organic compounds in soil and groundwater. The goal of the proposed research is to demonstrate the potential of using propane and butane-utilizing microorganisms to transform problematic CAH mixtures. The demonstration will be aimed towards creating in situ bioreactive passive barriers in contaminated aquifers. Oregon State University research with microorganisms stimulated on propane or butane has demonstrated the potential for transforming a broad range of CAH mixtures that have been problematic with other cometabolic substrates. Microcosm studies conducted with subsurface solids and groundwater from contaminated DOD sites, however, have shown that propane and butane-utilizers are often absent in the subsurface, or have long lag periods before effective stimulation is achieved. Thus the implementation of effective in situ treatment systems at many sites will likely require the bioaugmentation of enrichments. The proposed work will demonstrate effective methods to create passive treatment barriers through both bioaugmentation and the use of a subsurface delivery system. The bioaugmentation will serve only to add effective propane or butane-utilizers to the treatment zone. Microbial growth and maintenance for effective cometabolic treatment will be achieved through propane or butane addition to the subsurface. In addition, we will explore the use of mixed cometabolic substrates for the treatment of problematic CAH mixtures.

BENEFIT: The primary benefit from the outcome of this project will be a field documented in situ cometabolic process that transforms problematic mixtures of CAH's. This technology will be a new in-situ application of aerobic cometabolism for complex CAH mixtures. In addition, a bioaugmentation methodology for in-situ cometabolism will be developed to be possibly used as a remediation alternative for sites where natural attenuation or biostimulation will not work. This technology may be used a passive process that can be applied in deep aquifers or in a stratigraphy with multiple clay lenses. Other products from this research include developing an approach for establishing effective microbial communities for in-situ cometabolic treatment, modification to the Cometabolism Transport Model, assessment of community structure changes with bioaugmentation and cometabolic transformation, and specific probe method development for propane and butane bioaugmentation cultures.

TECHNICAL APPROACH & RISK: The technical approach will consists of four components:

1) Laboratory studies to select the bioaugmentation approach and to develop kinetic information for single substrate (propane or butane) and mixed substrate addition (propane and phenol, for example) for the transformation of CAH mixtures. 2) Explore molecular probe methods for tracking the bioaugmentation and biostimulation in laboratory and field studies. 3) Field demonstrations to evaluate the bioaugmentation approach and to determine the effectiveness in treating problematic mixtures of 1,1,1-TCA, 1,1-DCE, and TCE using propane or butane as a single cometabolic substrate, and mixed cometabolic substrates, propane or butane with phenol or toluene, in the latter stages of the field tests. 4) Modeling evaluations of the laboratory studies and the field studies, including simulations to aid in the design of the field demonstration tests.

ACCOMPLISHMENTS: This is a FY 1999 New Start.

TRANSITION: The project intends to transition through to the Environmental Security Technology Certification Program (ESTCP).

PROJECT SUMMARY

PROJECT TITLE & ID: Nonintrusive Characterization of Dense Nonaqueous Phase Liquids Using Short-Lived Radiotracers in Partioning Interwell Tracer Tests; CU-1128

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. DOE

LAB: Pacific Northwest National Laboratory - Richland, WA

PRINCIPAL INVESTIGATOR: Dr. Phillip A. Gauglitz

FY 1999 FUNDS: $503K

OBJECTIVE: The objective of the proposed research is to develop partitioning interwell tracer testing using short-lived radioisotopic tracers as an effective characterization technique for DNAPL in the either the saturated or unsaturated zone. We view this technique as the next evolution in partitioning tracer testing and offers significant benefits over currently available technology. By injecting conservative and partitioning short-lived radioisotopic tracers into the subsurface and continuously measuring their presence in monitoring wells with moveable downhole detectors, the location and amount of DNAPL can be measured to a much greater extent than can now be achieved by any other method.

BENEFIT: The proposed research will develop an innovative, nonintrusive radiotracer methodology for reliably detecting, quantifying, and determining the horizontal and vertical extent of non-aqueous phase liquids (NAPLs) in the subsurface environment. The desired information will be available in an easily interpretable format and will provide the ability to detect and delineate subsurface NAPLs at contaminated sites to an extent beyond any existing technology. This additional information will substantially improve the other efforts at a cleanup site, including risk assessment, remedial system design, optimization of remedial operations, and verification for site closure.

The proposed research will lead to a cost-effective technique for more precisely locating DNAPL sources, estimating the mass, and monitoring the transport and/or reduction of the mass over time, which are critical aspects of cost-effective cleanup. It is anticipated that the costs to implement the developed technology will be comparable to those of conventional partitioning interwell tracer tests, with significantly more characterization information achieved.

TECHNICAL APPROACH & RISK: The technical approach is to develop the radiochemical techniques for making tagged tracers together with assembling suitable detectors. After the field prototype has been tested, the tracers and sensors will be used in a field application to further develop the method. The field testing will be guided by detailed fluid flow modeling, as will the interpretation of the field results. The tasks for this project are: 1) Detector and Logging System Development, 2) Tracer Selection and Radiochemistry Techniques, 3) Laboratory Testing, 4) Pre-Test Modeling and Field Test Planning, 5) Field Testing, 6) Inverse Modeling (Data Analysis),and 7) a Guidance Document.

ACCOMPLISHMENTS: This is a FY 1999 New Start.

TRANSITION: The project intends to transition the complete package for deployment in saturated and/or unsaturated DNAPL zones within DoD sites. The technology will be deployable by site personnel or service companies. Interest has been expressed by Current Environmental Solutions, Inc. and others

PROJECT SUMMARY

PROJECT TITLE & ID: Biological Assessment for Characterizing Contaminant Risk at the Genetic-, Individual-, and Population-Level; CU-1129

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Army

LAB: Waterways Experiment Station - Vicksburg, MS

PRINCIPAL INVESTIGATOR: Dr. Todd Stephen Bridges

FY 1999 FUNDS: $514K

OBJECTIVE: The objective of this project is to develop a suite of technically defensible assays that can be effectively used in regulatory programs to quantify the ecological risk of contaminated sediments at the molecular-, individual-, and population-level. We will quantify the biological/ecological meaning of genetic responses, collected using genosensors, by way of comparison to whole-organism assessments of toxicity and modeled population-level impacts. Dose-response information will be simultaneously generated using genosensors and whole-organism bioassays for such military-relevant compounds as explosives (TNT, RDX, HMX), other organics (PCB/PAH), and metals (Pb).

BENEFIT: Currently there is a lack of defensible methods to measure and assess ecosystem responses to insults by DOD relevant contaminants. Large uncertainties surround current cleanup goals for military-unique contaminants (MUCs) and estimates of environmental risk resulting from exposure to MUCs. The large assumptions and extrapolations required by current approaches necessitates the use of large safety/uncertainty factors which lead to very conservative cleanup goals that are very expensive to obtain with current cleanup technologies. This project will provide tangible benefits to DoD cleanup efforts by reducing the driving uncertainties in the estimation of risk in MUC contaminated sediments, namely, 1) contaminant bioavailability, 2) the toxicity of MUCs, 3) the toxicity of complex MUC mixtures, and 4) extrapolating to higher order effects (e.g., population-level impacts). The methods and data generated during this project will improve DoD's capability to defensibly define risk to aquatic organisms exposed to MUCs and to set reasonable cleanup levels that are based on the potential for toxicity at multiple levels of biological organization. Given the number of contaminated DoD/DoE sites (17,000), the potential for remedial cost avoidance is considerable.

TECHNICAL APPROACH & RISK: During the first phase of this project, 1) sediments will be spiked with single military-relevant compounds (i.e., explosives and other organics) and mixtures at a range of concentrations, 2) sediment-dwelling organisms will be exposed to these contaminated sediments, 3) the sediments and organisms will be screened for the presence of genetic markers using developed genosensors, and 4) whole-organism effects on survival, growth and reproductive endpoints will be measured.

The Genosensor consists of nucleic acid hybridization probes covalently bonded to discretely addressable ordinates on a glass chip. When a complex mixture of nucleic acids is labeled with a fluorescent tag and flowed through a channel glass genosensor, it will bind in a pattern that reflects the nucleotide sequence(s) (i.e., genes) contained in the sample. Bulk RNA will be extracted from whole organisms, then the transcripts will be converted to cDNA using Reverse Transcriptase-PCR and Arbitrary Primer PCR protocols. A second (untargeted) approach will be taken using a new oligonucleotide fingerprinting strategy, known as Arbitrary Sequence Oligonucleotide Fingerprinting (ASOF), to detect and isolate previously unknown gene transcripts associated with cellular responses to stress and DNA damage.

Four sediment-dwelling organisms will be used in this project that are currently being used by EPA and the Corps to develop chronic, sublethal sediment bioassays for national regulatory programs. Two of the species occur in marine habitats (Neanthes arenaceodentata and Leptocheirus plumulosus) and two of the species are found in freshwater habitats (Hyalella azteca and Chironomus tentans). Impacts at the population-level will be projected using population models developed for bioassay organisms during the course of this study. By simultaneously measuring biological responses at three distinct levels of biological organization (i.e., genes, whole organisms, populations) we will have the ability to effectively test the reliability of estimating potential risk at higher levels of organization (e.g., ecosystems) using information that can be quickly and inexpensively collected at lower levels of organization (i.e., the level of genes).

During the second phase of study, the bioassay suite will be tested using naturally contaminated sediment containing even more complex mixtures of military-relevant and conventional contaminants. The comparisons made among the endpoints at each level of organization using field collected sediments ranging in degree of contamination will allow us to test how robust our predictions will be under a regulatory use scenario.

ACCOMPLISHMENTS: This is a FY 1999 New Start.

TRANSITION: The project intends to transition through to the Environmental Security Technology Certification Program (ESTCP).

PROJECT SUMMARY

PROJECT TITLE & ID: Evaluation of Performance and Longevity at DoD Permeable Reactive Barrier Sites; CU-1140

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: Naval Facilities Engineering Service Center (NFESC), Port Hueneme, CA

LAB: U.S. Navy - NFESC

PRINCIPAL INVESTIGATOR: Mr. Chuck Reeter

FY 1999 FUNDS: $250K

OBJECTIVE: The purpose of this DoD (SERDP/ESTCP) project and its two companion projects (DOE and EPA) is to achieve combined Federal agency coordination in addressing these various performance and longevity issues at specific PRB projects. The DoD, EPA, and DOE projects are being executed simultaneously for a leveraged effort that will achieve maximum coordination to minimize duplication and to ensure that the most cost-effective measures will be implemented. Project coordination will ensure that data collected from each site are comparable, while allowing each agency to focus on its unique needs.

BENEFIT: Considering the EPA suggested 5,000 sites contaminated with chlorinated compounds and using the previously discussed EPA 10-20% figure, it is estimated that potentially 500-1000 sites could use the PRB technology, of which the Navy, Air Force, and Army would have the vast majority. There are a number of different ways to calculate cost benefits. Using actual site specific data from cost analyses performed at one Navy location, the results can typically represent most DoD sites. At NAS Moffett Field, it would cost about $9 Million (M) to remediate the site by using a full-scale PRB over a 50-year period. Conversely, it would cost about $33M over a 50-year period using the groundwater pump-and-treat method. Specifically for Moffett, over the long term, the cost savings ratio of using the PRB technology over pump-and-treat can be as much as 4 times. Overall, it is estimated that the Moffett site can save about $24M in contaminant plume remediation costs. It is reasonable to conclude that over the long term, $$ Billions could be saved at hundreds of chlorinated compound contaminated sites where the PRB technology can potentially be applied.

TECHNICAL APPROACH & RISK: Site-specific conditions should be the ultimate factor in designing a PRB remediation solution and the site performance and compliance monitoring plan should evaluate its operating effectiveness. Because the main goal of installation cleanup is to ensure that contamination is remediated and ultimately prevented from progressing further downgradient of the site, monitoring is needed to evaluate the capture and treatment efficiency of the PRB configuration. Since all current PRBs have somewhat different design configurations, it will be important to evaluate certain selected sites using a consistent approach. This SERDP/ESTCP project is intended to specifically focus on the DoD sites, only. The EPA and DOE will provide separate funding for their selected sites. Similar to the DOE and EPA projects, the DoD SERDP/ESTCP project approach will be conducted using the following tasks:

(1) Field Monitoring Survey and Site Selection, (2) Performance Sampling at Selected PRB Sites, and (3) Performance Data Evaluation.

ACCOMPLISHMENTS: This is a FY 1999 New Start.

TRANSITION: The project intends to transition through to the Environmental Security Technology Certification Program (ESTCP).

PROJECT SUMMARY

PROJECT TITLE & ID: Environmental Toxicology Earmark; CU-1141

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: Brooks Air Force Base, Port Hueneme, CA

LAB: Texas Tech University

PRINCIPAL INVESTIGATOR: Dr. Daniel Erwin

FY 1999 FUNDS: $2,700K

OBJECTIVE: There are two objectives of this earmark project:

1) Develop a scientifically-based environmental standard for JP-8 jet fuel exposure of the general population at Air Force bases with the intent to characterize potential acute health effects associated with JP-8 and recommend actions to ameliorate disease/injury in exposed personnel.

2) Perform ecological risk assessment/modeling of contaminant mixtures that will: a) develop/validate aquatic models for assessing effects of water-borne contaminants on aquatic fauna development and reproduction; b) develop and validate terrestrial models for assessing effects of contaminants on terrestrial species development and reproduction; and, c) integrate data using models and GIS to predict the effects of contaminants on both individuals and populations.

BENEFIT: The proposed research will address mixtures in a risk-based approach providing cutting edge science to the Department of Defense to address regulatory mandates they are facing related to site remediation and base closures. This research will be accomplished through the integration of classical toxicology, chemistry, epidemiology, and modeling.

TECHNICAL APPROACH & RISK: *Jet Fuel (JP-8) Health Risk Assessment and Epidemiology Study* (Planning Process and Implementation of Pilot Project). The project plans to develop a scientifically based environmental standard of jet propulsion type 8 jet fuel (JP-8) exposure for the general population at USAF bases. In addition this project will: (1) assess the environmental impact of jet fuel use, thereby understanding the parameters required to achieve a safe community environment; and (2) characterize the potential acute health effects associated with JP-8 and recommend actions to ameliorate disease/injury in personnel exposed to jet fuel.

Ecological Risk Assessment/Modeling - Mixtures This task will focus on four areas:
A. Aquatic Toxicology: To develop and validate aquatic models for assessing the effects of water-borne contaminants on the development and reproduction of aquatic fauna in and around USAF bases. Determine effects of contaminant mixtures on development and reproduction of aquatic fauna. Determine the effects

of larval exposure to contaminant mixtures on adult reproductive parameters. Development of scientific data relative to exposure of adult versus juvenile animals in the aquatic fauna. Evaluation of non-lethal bio-markers of amphibian and fish that can be used in extrapolation and risk assessment following exposure to mixtures. Provide data on aquatic exposure for further extrapolation and risk assessment of environmental chemical mixtures.

B. Terrestrial Toxicology: Determine the effects of mixtures (AP, Cd and As) on development, growth, and reproduction at postnatal day 21 and 70, following in-utero and lactational exposure of deer mice (Peromyscus maniculatus). Evaluate steroid-metabolizing enzyme profiles in liver or gonads of mice following exposure to these mixtures. Investigate wild rodents from terrestrial field experiments. Development of scientific data relative to exposure of adult versus juvenile following in utero and lactational exposure to mixtures (AP, Cd and As) using a wildlife sentinel rodent model (peromyscus maniculatus). Evaluation of non-lethal biomarkers that can be used in extrapolation and risk assessment following exposure to mixtures. Provide data on terrestrial exposure for further extrapolation and risk assessment of environmental chemical Analytical Evaluations in Support of Toxicological Evaluations. Analytically evaluate ammonium perchlorate in environmental samples using ion chromatography. Determine ammonium perchlorate partitioning behavior between n-octanol and water. Determine the fate of ammonium perchlorate in aquatic systems in a way similar to hydrolysis studies used in the registration of agrochemicals. Determine leaching behavior of ammonium perchlorate in soil using characterized soil columns.

C. Analytical Evaluations in Support of Toxicological Evaluations: Basic environmental chemistry information on ammonium perchlorate

D. Environmental Modeling: Two integrated models will be developed based upon the laboratory and field experiments: 1) An Aquatic Model to predict effects of ammonium perchlorate on frog and fish populations, 2) A Terrestrial Model to predict effects of ammonium perchlorate on small mammal populations

ACCOMPLISHMENTS: This is a FY 1999 New Start.

TRANSITION: Identification and validation of bio-markers associated with exposure to JP-8 fuel which will provide the Air Force with immediate tools for risk assessment. Development and validation of bio-markers following exposure of amphibians, fish and rodents to chemical mixtures which can be used by the Air Force in future risk assessment of chemical mixtures.

APPENDIX B

Compliance Project Summaries

PROJECT SUMMARY

PROJECT TITLE & ID: Compact, Closed-Loop-Controlled Waste Incinerator; CP-34

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Navy

LAB: Naval Air Warfare Center - China Lake, CA

PRINCIPAL INVESTIGATOR: Dr. Klaus Schadow

FY 1998 COMPLETED PROJECT

OBJECTIVE: This project established the Science and Technology (S&T) basis for a compact, closed-loop-controlled waste incinerator using resonant acoustics for enhanced waste pyrolysis and controlled vortex dynamics for enhanced and controlled after-burning. The after-burning process is closed-looped controlled using diode-laser based sensors for real-time and continuous emission monitoring, new types of actuators, and a non-standard controller based on fuzzy logic or neural nets. A second SERDP project, **CP-887 Demonstration of a Compact, Closed-Loop-Controlled Waste Incinerator,** applies this new technology to two Navy incinerator programs (see Project Summary for CP-887 in this Appendix).

BENEFIT: Successful demonstration of a compact incinerator with real-time exhaust monitoring for active combustion control represents a significant step towards assured waste incineration and can be the basis for next-generation incinerators. The compact-incinerator technology, specific to shipboard applications, is essential for the development of environmentally sound ships beyond the year 2000. Compact incinerators also are desirable for on-shore use in the government and private sectors. Small, compact incinerators allow on-site waste destruction and avoid waste transportation to large incineration sites. The closed-loop, active control of the incineration process assures proper incineration. For shipboard application this will result in significant cost savings by avoiding costs for waste off-loading and on-shore destruction, particularly in foreign countries.

ACCOMPLISHMENTS: In FY 98, this project focused on two areas: improvement of the after-burner using active combustion control, and improvement of the sludge incinerator using resonant acoustics. Using a 50kW actively controlled after-burner, progress was made in four areas: (1) carbon monoxide and NOx emissions were reduced using realistic, hot waste gases (115 BTU/ft^3) and operating temperature (700F); (2) the after-burner was re-designed for extended duration with hot pyrolysis gases; (3) data acquisition and analysis hardware for the diode-laser sensor system were improved; (4) the fuzzy controller was adapted to the current after-burner geometry and unsteady pyrolysis gas mass flow; and (5) failure modes were determined for incineration in actively established vortices. Additional accomplishments included: (1) the feasibility of using diode-laser based sensors under practical operational conditions was demonstrated for real time monitoring of combustion processes inside the combustor and critical species (CO, C_2H_4, and C_2H_2) in the exhaust; (2) closed-looped active combustion control was achieved based on

data from the diode-laser based sensors; and (3) the 1-dimensional engineering model was applied to the after-burner: good agreement between experimental and predicted values for NOx and CO was obtained.

TRANSITION: Continuing interaction is taking place with the Navy for multi-functional incinerators (for sludge and oil), demonstrating acoustics retrofits, and developing an after-burner for another DoD facility under a joint development program. Three marine incinerator manufactures interested in collaborating have been identified and a proposal for collaboration with one has been developed. The Principal Investigator is pursuing future DoD funding for a compact, integrated system for hazardous waste incineration at DoD facilities and for 6.4 research funding for shipboard advanced incineration.

PROJECT SUMMARY

PROJECT TITLE & ID: Reduction of NOx Emissions from Marine Power Plants; CP-42

RESEARCH CATEGORY: 6.4 Demonstration and Validation

LEAD AGENCY: U.S. Navy

LAB: Naval Surface Warfare Center - Annapolis, MD

PRINCIPAL INVESTIGATOR: Dr. Herman Urbach

FY 1998 COMPLETED PROJECT

OBJECTIVE: In response to potential violations of proposed emission limits for NOx from diesel engines on ships, the Navy sought to develop a low-risk, low-cost, technology using injection timing retardation, exhaust-gas recirculation, and water injection. The objective of this project was to evaluate NOx-reducing technologies using realistic shipboard conditions, including the ability of a technology to operate without unscheduled power losses in a tactical, at-sea operating scenario.

BENEFIT: The results of this project allows the Navy to comply with regulations governing NOx emissions for maritime diesel engines. It will permit the Navy to avoid litigation and to operate in zones subject to strict limitations of NOx emissions, such as the California littoral and congested European ports.

ACCOMPLISHMENTS: Tests showed that two-stroke, turbocharged, marine diesel configurations combining exhaust-gas recirculation, retardation of injection timing, intercooling, and an oxidation catalyst for the combustion of volatile organic compounds (VOCs) and particulates, lowers NOx-emission levels to below EPA mandates. In addition, the new system reduced carbon monoxide and particulate matter below mandated levels without loss of rated power. Water-injection into the combustor of the LM2500 engine reduced the NOx emissions to the planned objective level of 42 ppm during steady-state engine operations at all levels of throttle output power. Particulate-emission tests on the diesel engine were completed at 96 percent load levels. The measurements averaged 0.25 g/kWh (less than half the proposed EPA standard of 0.54 g/kWh) with NOx levels below 9.0 g/kWh. These tests conducted the NOx control evaluation at constant speed (1800 rpm). A DDC 4-71 diesel engine was modified to retard the timing of fuel injection, to introduce exhaust gas recirculation, and to inject water in the form of an emulsified, fuel-water mixture. The manually-controlled system was tested at research facilities of the North Carolina State University prior to testing in a Yard Patrol (YP) craft at the Naval Academy, Annapolis. Studies assessed the risks of erosion/corrosion in the fuel injectors, flame quenching, and/or cylinder misfiring. All ship-system impacts were accessed at-sea in the YP.

TRANSITION: Several commercial vendors have expressed interest in further developing these technologies for the Navy. Specifically, a dual-application proposal has been submitted to the Navy to test either an LM2500 or an LM6000 equipped with both water-fog injection and steam injection.

PROJECT SUMMARY

PROJECT TITLE & ID: Advanced Mass Spectrometry for Atmospheric Monitoring; CP-192

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Air Force

LAB: Air Force Research Laboratory - Kirkland Air Force Base, NM

PRINCIPAL INVESTIGATOR: Dr. John O. Ballenthin

FY 1999 FUNDS: $100K

OBJECTIVE: This applied research effort is developing and demonstrating technology to measure the concentrations of trace gas-phase neutral species in the stratosphere, troposphere, and ground level atmosphere. This technique is broadly applicable to the SERDP Compliance pillar by providing an effective, robust, portable apparatus capable of detecting major and minor pollutants with a greater than trillion-to-one dynamic range and part-per-quadrillion sensitivity.

BENEFIT: This research program will lead to high sensitivity measurements of the concentrations of many chemical species at ground level and in the troposphere and stratosphere. Models of the chemistry of polluted environments can be improved by adjusting the model to match the measurements. The validated models can then be applied with confidence to environmental scenarios where direct measurements have not been made. An immediate benefit of the research will be to ensure compliance of jet- or rocket-engine emission with mandated standards and to support Department of Defense (DoD) efforts to reduce pollution from jet and rocket operations. The end-product of the research will be a portable, highly-sensitive, calibrated, and tested instrument that will be suitable for commercialization and use by the environmental monitoring community.

TECHNICAL APPROACH AND RISKS: This effort is capitalizing on the chemical reactions between neutral pollutant gas molecules and naturally present, atmospheric ions which often produce new ion species that are unique signatures of the original trace neutral. Because of the very small background signal level for ions, the technique routinely provides sensitivities to detect neutrals in the parts-per-quadrillion levels. Risks have been minimized since the concept has been developed and proven by laboratory measurements. The prototype mass spectrometer has already been demonstrated to function in upper tropospheric and lower stratospheric measurements of jet engine exhaust composition. The critical path to program completion will be: develop and demonstrate the capability of a portable system for jet, rocket and other plume measurements with comparisons with competing instrumentation; demonstrate the capability of the system for analysis of complex pollutant mixtures present in such sources as jet engines test cells and stack processes; and perform laboratory measurements of trace neutral ion chemistry of relevant species.

ACCOMPLISHMENTS: In FY 1998, three instruments were fabricated, tested and used in field applications resulting in sub-part-per-trillion sensitivity and retaining required measurement selectivity against interferences. Relevant ion reactive rates were published in refereed journals, enabling the expansion of the measurement technique to new disciplines.

TRANSITION: Seventeen technical papers and 23 conferences/symposia presentations have enabled results from validation measurements to be distributed to the user community including: the SMC/CLN Rocket Impact on Stratospheric Ozone Program, the NASA Atmospheric Effects of Aviation Program, the WL/POSF Halon Combustion Measurements, and National Oceanic Partnership Program (Navy). The technology is directly applicable to mass spectrometric instrumentation companies.

PROJECT SUMMARY

PROJECT TITLE & ID: Kinetics of Supercritical Water Oxidation; CP-364

RESEARCH CATEGORY: 6.1 Basic Research

LEAD AGENCY: Department of Energy

LAB: Sandia National Laboratory - Livermore, CA

PRINCIPAL INVESTIGATOR: Dr. Steven F. Rice

FY 1998 COMPLETED PROJECT

OBJECTIVE: The objective of this project was to develop a supercritical water oxidation (SCWO) technology to treat aqueous wastes. SCWO is an emerging technology under development at several laboratories, including Sandia National Laboratory, for the treatment of hazardous wastes such as obsolete chemical munitions, mixed wastes, and naval shipboard excess hazardous materials. Understanding of the rates and mechanisms of reactions in supercritical water was limited to a handful of empirical rate expressions for very simple chemicals. These expressions were of limited use in the formulation of predictive models of SCWO for the design and operation of large-scale waste processing equipment. To be applicable as design tools, the models needed to be based on elementary reaction steps or, at minimum, a detailed quantitative mechanistic description incorporating all the key fundamental reactions. Basic research was needed to improve the ability to predict reaction rates in supercritical water. The project was designed to result in a user-friendly, computer-based model that could predict reaction rates and conversion efficiency for a wide range of waste feeds and reactor conditions.

BENEFIT: The SCWO process, operating at two orders of magnitude greater density than atmospheric gaseous combustion, provides high reaction rates at moderate temperatures. The technical chemical engineering literature contains results of studies of SCWO measuring destruction efficiencies for a variety of waste chemicals and mixtures. Some of these data can be used to generate empirical, global kinetic rate expressions for a select list of simple species. However, the in-situ measurements used in this project, particularly on intermediates, lead to valuable information for predictive model development. The improved understanding of reaction rates and the kinetic models developed by this project have produced advanced strategies for reactor design and improved methods for commercial system optimization.

ACCOMPLISHMENTS: This project developed oxidation rates for common organic compounds in supercritical water. These data provide the basis to develop a model (combustion-based as opposed to liquid-phase oxidation) to be used as a design engineer's tool for testing the effects of reactor design changes and producing advanced strategies for large-scale system optimization.

TRANSITION: In addition to presentations at technical meetings and publication in peer-reviewed literature, results from this project are made available to a wide distribution within the SCWO technical community. Additional transition will occur with indirect support on leveraged projects with the Defense

Advanced Research Projects Agency (DARPA) and the Office of Naval Research (ONR) for shipboard waste, with the U.S. Army Applied Research, Development and Engineering Center's (ARDEC) Pine Bluff Arsenal Unit, and at the U.S. Army Aberdeen Proving Ground. Coordination with ARDEC on the ESTCP-supported Pine Bluff Arsenal SCWO plant start-up project has influenced the installation of the reactor skids.

PROJECT SUMMARY

PROJECT TITLE & ID: Lead-Based Paint Hazard Mitigation; CP-521

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Army

LAB: Construction Engineering Research Laboratory - Champaign, IL

PRINCIPAL INVESTIGATOR: Dr. Ashok Kumar

FY 1998 COMPLETED PROJECT

OBJECTIVE: The technical objectives of this project were: (1) to develop and demonstrate novel vitrification technology using thermal spray or microwave energy for lead-based paint removal and disposal that can be used effectively for immobilization of heavy metal hazardous waste, and (2) to evaluate other emerging technologies for lead-based paint abatement. Currently used abatement technologies result in the emission of hazardous lead dusts as well as hazardous waste. Environmental contamination by fugitive dust emissions is regulated under the Clean Air and Clean Water Acts while the Resource Conservation and Recovery Act (RCRA) addresses the proper disposal of lead-bearing wastes.

BENEFIT: The most significant benefit of this work is the optimized management of lead-based paint hazards and the increased protection of the health of DoD personnel and their families. Enhanced quality of life for soldiers and their families leads to increased troop retention and a more capable force. Improved lead-based paint abatement technologies also help reduce the cost of lead-based paint hazard mitigation which is estimated to exceed $1 billion for Department of Defense (DoD) installations.

ACCOMPLISHMENTS: Laboratory experiments with the microwave paint removal system were successful in establishing the optimal conditions for easy lead-based paint removal, which were obtained using chemical stabilizers (calcium silicate based PreTox 2000) in conjunction with nonflammable, graphite-based microwave susceptors. Polyaniline susceptors were also tested successfully. The temperature needed to soften the lead based paint by microwaves for easy removal was about 100°C. By using a cementitious coating in the PreTox, the fire hazard was reduced. Nonhazardous waste product was obtained. Toxicity Characteristic Leachate Procedure (TCLP) testing revealed that the paint scrapings from this process leached less than 5 ppm lead).

Self-healing latex coatings and elastomeric encapsulates filled with calcium hydroxide and polymer were formulated and tested in the laboratory. These self-healing coatings can be used to overcoat lead-based paint to reduce hazardous lead dust, which is produced when the paint is damaged.

The lead-based paint hazard management system (LHM) Painter-L was completed and beta-tested. The LHM, jointly developed by the Army and Navy, integrates data from paint inspections, lead dust, and soil samples to produce a lead hazard management plan and the required lead hazard disclosure report. Data

from Army installations such as Carlisle Barracks, PA, were put in the system and a hazard abatement plan developed and presented to the installations engineers.

TRANSITION: Transfer of the technology is occurring within the DoD via demonstration/validation in Environmental Security Technology Certification Program (ESTCP)-funded projects for thermal spray vitrification and microwave paint removal. Collaboration with the private sector includes: licensing agreements for patents, CRADA development, commercialization efforts, and journal articles and presentations at trade shows. Additional documents are being developed for use by the Tri-Service user community, including Guide Specifications, Technical Manuals, User Guides, and an ASTM standard for abatement of lead hazards in buildings.

PROJECT SUMMARY

PROJECT TITLE & ID: National Environmental Education and Training Center (NEETC); CP-819

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Army

LAB: Waterways Experiment Station - Vicksburg

PRINCIPAL INVESTIGATOR: Dr. Raymond Lovett

FY 1999 FUNDS: $1500K

OBJECTIVE: New environmental technologies are often designed for efficacy with little consideration given to the safety of the technology to an operator, a maintenance worker or the community. As a result, significant time and energy is spent on re-engineering technologies to address health and safety issues. This project seeks (1) to create, as an effective, deliverable tool for technology developers, a knowledge-based prototype system (TEXPERT) which will evaluate and incorporate health and safety concerns into the design of environmental technologies, and (2) to improve health and safety information and its dissemination during technology deployment.

BENEFIT: This safety and health evaluation tool, when coupled with existing "engineering design and management tools" will assist designers and technology "gatekeepers" in evaluating and assessing safety and health issues in a focused, systematic way during technology development. It will lead to a consideration of "downstream" worker and environmental safety and health implications associated with field (or production) use of innovative technology, and minimize the occurrence of safety and health concerns before and during end-user implementation. It will also make available worker safety and health training at plant start-up to ensure safe operation of the technology.

TECHNICAL APPROACH AND RISKS: TEXPERT will be implemented on the World Wide Web. The new system will provide new technology developers with access to an "occupationally and environmentally focused total system design assessment tool" through a World Wide Web site that will be linked to databases and software tools (Environmental Protection Agency formats) on safety and health associated with known technologies, risk assessment, preliminary hazard recognition and analysis, fault-tree analysis, job safety analysis, etc.

ACCOMPLISHMENTS: In FY98, four Technology Transfer Centers were visited and surveyed: (1) National Institute for Environmental Renewal (NIER), Scranton, PA; (2) Center for Hazardous Materials Research (CHMR), Harmarville, PA; (3) National Defense Center for Environmental Excellence (NDCEE), Johnstown, PA; and (4) Center for Technology Transfer, Wheeling, WV. The survey report showing the utility of the proposed TEXPERT system to these organizations, has been written. To support TEXPERT, work continued on identifying technology elements within environmental process, and developing "part families," which link design attributes to safety and health issues, in order to build "front-

end" databases, as well as "back-end" assessment and risk databases. An expert system shell has been purchased and initial coding for web accessibility has begun but the expert system is not yet accessible via the Internet.

Filter Press technology has been selected as sample technology for developing a methodology and a protocol for creating safety and health training materials. A draft technology safety data sheet has been written, and information required to write a model training module was gathered.

In order to model community and work force issues in environmental remediation technology development, a draft manual "Environmental Restoration Opportunities at Military Facilities: Community Participation and Workforce Involvement" was written. The summary was distributed among military participants on the Base/Community Restoration Roundtable.

TRANSITION: Transition is an ongoing part of this project and will consist of full implementation of an expert system made available on the Internet or on diskette, demonstration at two technology development sites, and integration with a similar DOE program. Implementation of an outreach program via the Internet is also planned.

PROJECT SUMMARY

PROJECT TITLE & ID: Demonstration of Compact, Closed-Loop-Controlled Waste Incinerator; CP-887

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Navy

LAB: Naval Air Warfare Center - China Lake, CA

PRINCIPAL INVESTIGATOR: Dr. Klaus Schadow

FY 1998 COMPLETED PROJECT

OBJECTIVE: The objective of this project was to apply the technical basis of new compact, closed-loop-controlled waste incinerator technology developed in project **CP-034** to two specific Navy incinerator programs: (1) development of a compact and efficient afterburner for a plasma arc thermal destruction system, and (2) a sludge incinerator for black-water destruction.

BENEFIT: Successful shipboard demonstration of a compact incinerator with real-time exhaust monitoring for active combustion control represents a significant step towards assured waste incineration and can be the basis for the next generation incinerators. The compact-incinerator technology will be essential for the development of environmentally sound ships beyond the year 2000. Compact incinerators are also desirable for on-shore use in the government and private sector. Compact incinerators will allow on-site waste destruction and avoid waste transportation to large incineration sites. In particular, medical waste incineration is a prime candidate in the private sector for a compact system. The closed-loop, active control of the incineration process will for the first time assure proper incineration during design and off-design operation. Successful demonstration of the assured waste incineration on-board ships will result in significant cost savings by avoiding the cost of waste off-loading and on-shore destruction, particularly in foreign countries.

ACCOMPLISHMENTS: In FY 1998, a new afterburner was initially tested at full scale (680kW) with cold ethylene and nitrogen. Extremely low emissions for CO (<35 ppm) and NOx (<30 ppm) were achieved at only 46 msec residence time, which corresponds to a very compact system. Subsequently the afterburner was evaluated with hot, sooty pyrolysis gases, which were synchronously injected into acoustically stabilized air vortices to achieve significant reductions in emissions and increases in destruction efficiencies. No visible emissions remained and the CO levels were as low as 32 ppm. NOx was about 35 ppm for a residence time of about 62 ms.

The performance of the afterburning process was monitored with diode-laser sensors for direct measurements of CO and instantaneous temperature fluctuation in the combustor. A correlation between the concentrations of CO and the magnitude of temperature fluctuations (corresponding to vortex coherence) was established and utilized for the control strategies. The closed-loop control system was

highly successful and adaptively optimized the afterburner performance within 100 ms at an optimized control strategy.

This project resulted in the development of the controlled after-burner for a specific incinerator (a modified GS500 pyrolysis chamber). Enhancements to the design and increasing the fuel gas path, to accommodate the greater gas volumes and decreased gas density due to the hot pyrolysis gases, were successful.

Acoustic enhancement of the Navy black-water sludge incinerator did not produce the desired results. It was concluded that re-design of the incinerator is necessary. Tests were performed with the new sludge incinerator concept with direct sludge injection into the exhaust of a pulse combustor. This study did not prove whether sludge incineration is enhanced or hindered by the presence of acoustic forcing, because of the large heat losses present in the incinerator that was used. Further testing is needed to make an adequate assessment of the impact of pulsations on sludge incineration.

TRANSITION: Continuing interaction is taking place with the Navy for: multi-functional incinerators (for sludge and oil), demonstrating acoustics retrofits, and developing an afterburner for another Department of Defense (DoD) facility under a joint development program. Three marine incinerator manufactures interested in collaborating have been identified and a proposal for collaboration with one has been developed. The Principal Investigator is pursuing future DoD funding for a compact, integrated system for hazardous waste incineration at DoD facilities and for 6.4 research funding for shipboard advanced incineration.

PROJECT SUMMARY

PROJECT TITLE & ID: Development of Non-Thermal Plasma Reactor Technology for Control of Atmospheric Emissions; CP-1038

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: Department of Energy

LAB: Los Alamos National Laboratory - Los Alamos, NM

PRINCIPAL INVESTIGATOR: Dr. Louis Rosocha

FY 1999 FUNDS: $725K

OBJECTIVE: The overall objective is to evaluate and develop new non-thermal plasma (NTP) reactor technology for DoD air emissions control applications and provide a basis for selecting the most appropriate NTP technology for DoD applications. This will be accomplished by evaluating the performance of prototype and pilot-scale NTP reactors (i.e., corona, dielectric barrier, and electron beam) for Nitrogen Oxide (NOx) and Hazardous Air Pollutant (HAP) abatement and specialized Volatile Organic Compound (VOC) control. The development of an efficient, reductive-model NOx processor is a key goal.

BENEFIT: All organizations within the DoD, the Department of Energy (DOE), and industry affected by the need to control emissions of NOx, HAPs, and VOCs will benefit from the development of a flexible technology for emissions control and a basis of selecting the most appropriate technology for specific needs. With the successful development and implementation of NTP technology, present and planned missions can proceed without deleterious environmental impacts or major compliance-issue and cost escalations. Particular technical impacts are an increase in the efficiency of electric-discharge NTP (by control of discharge physics and plasma chemistry) and the potential for development of low back-pressure, filterless, scrubberless NOx control equipment using reductive mode processing, effected by improved electrical driver technology. Also, other VOC-abatement technologies are not yet fully proven, therefore, NTP can be a promising back-up in some cases.

TECHNICAL APPROACH AND RISKS: After a comparative assessment of electric-discharge driven and electron-beam driven NTP reactors, reaction kinetic models, predictive simulation models, reactor scaling criteria, and optimization models will be developed. Scaling studies will be initiated with laboratory-pilot apparatus followed by reactor scale-up, optimization, and system engineering to the point of design of a field-pilot unit, which will be constructed and tested at a selected DoD site. This will provide criteria for selecting the most appropriate NTP technology for DoD applications. A cost-benefit assessment for NTP technology application to NOx and VOCs will also be performed.

The comparative assessment work builds on a 1995 National Institute of Standards and Technology (NIST) workshop on NTP applications to air pollution control. NIST also assists in plasma chemistry model

development and laboratory measurements of reaction-chemistry relevant parameters. Reactor performance is measured using gas chromatography/mass spectrometry, tunable diode laser, and laser induced fluorescence (LIF) probes, with Army Research Laboratory (ARL) taking the lead on optical/laser measurements. ARL also performs CFD (computational fluid dynamics) calculations to predict and optimize fluid flow patterns and treatment residence times. The Los Alamos National Laboratory focuses on electric discharge physics, electrical drive circuit engineering and optimization, and the design and construction of laboratory test, pilot, and scaled-up reactors.

ACCOMPLISHMENTS: In FY 1998, bench-top NTP reactors were set up for completing scale-up and optimization tests, and for testing a novel hydrid NTP-absorber concept. The formulation and documentation of scaling and optimization models for NTP reactors were completed and used to conduct an initial feasibility analysis for hybrid NTP reactors.

A specialized NTP reactor was constructed and tested at Los Alamos National Laboratory to evaluate a nitrogen (N-atom)-radical injection scheme for reductive NOx removal. Small-scale tests were successful but an assessment must be conducted to determine if this scheme is economical at a larger scale. A second reactor, with residence-time and optical-diagnostics capabilities, was tested for the removal of jet-engine exhaust stimulants. Additionally, a novel, bench-scale, high-speed electrical-discharge reactor was set up to examine the feasibility of direct reductive NOx removal.

A chemical-kinetics model was integrated into the Computational Fluid Dynamics (CFD) model to simulate de-NOx and HNO_3 formation. Test cases were run to show spatial and temporal accumulation profiles of HNO3 for four discharge sites. In addition, a database of chemical kinetics of reactions of neutral species in air relevant to NTPs was developed (125 reactions and temperature and pressure effects can be accounted).

The initial economic analysis of flue-gas processing using NTP technology was completed.

TRANSITION: The transition plan for this project involves coordination with users, coordination with industry, and full-scale implementation within DoD/DOE. User coordination includes: Air Force NOx abatement projects, jet-engine test cell and diesel-engine NOx abatement, VOC control at Tinker Air Force Base, emission control for the "Burn Box" at the Army's Aberdeen Test Center, and multi-agency interfacing via Los Alamos Environmental Management (EM) and DoD Program Managers. Industry coordination includes existing technology-commercialization Cooperative Research and Development Agreements (CRADAs) with the Electric Power Research Institute (EPRI) and High Mesa Technologies (HMT), potential future CRADAs with HMT and Environmental Elements, and Los Alamos Industrial Partnership Office promotion of industrial interaction. An industrial partner will be identified during the transition phase of this project and full-scale implementation will occur through a demonstration/validation project with the Environmental Security Technology Certification Program (ESTCP).

PROJECT SUMMARY

PROJECT TITLE & ID: Development and Integration of Laser-Based Sensors for VOC/NOx and Metals Emissions Monitoring; CP-1060

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: Department of Energy

LAB: Sandia National Laboratory - Livermore, CA

PRINCIPAL INVESTIGATOR: Dr. Scott Bisson

FY 1999 FUNDS: $910K

OBJECTIVE: The objective of this project is to develop a combined laser-based system for monitoring Volatile Organic Compounds/Nitrogen Oxides (VOCs/NOx) and metals for compliance with the Clean Air Act Amendments of 1990. For gaseous pollutants, an infrared (IR) spectrometer based on the new, periodically-poled, lithium niobate (PPLN) laser technology will be used. For metals emissions monitoring, the technique of laser induced breakdown spectroscopy (LIBS) will be employed.

BENEFIT: If successful, this technology would allow, for the first time, near real-time, in-situ analysis for monitoring a wide range of species (metals and gases) with higher sensitivity than previously achievable. There are also potential applications in process control and atmospheric chemistry research. Moreover, the compact size of this new system is attractive, making a portable system a possibility, and its cost is anticipated to be competitive with many conventional, laboratory analytical services.

TECHNICAL APPROACH AND RISKS: For development of the IR Spectrometer, the tunability, spectral bandwidth, and oscillation threshold of the PPLN source will be characterized. Given the wide range of species to be detected and the fact that the absorption spectra span the infrared, broad tunability will be essential. Reduction of the oscillation threshold will be attempted. The detection sensitivity will also be optimized through the use of acoustically resonant cells.

For development of the portable LIBS (PLIBS), currently available solid-state diode lasers will be identified and evaluated for long-term operation. The feasibility of using a solid-state laser for plasma ignition and spark generation will be investigated. If successful, this would reduce the physical dimension and weight of the LIBS system substantially and move one step closer to the portable unit proposed. Other compact lasers such as a diode-pumped Nd:YAG laser will also be evaluated. A thumbnail-sized microspectrometer will be employed for the PLIBS system (patent-pending).

For actual hardware integration, the goal is to exploit commonality between the IR spectrometer and the LIBS instrument to the extent possible but without sacrificing performance. Three areas of instrumental commonality between the two components have been identified. These are the laser source, the sample interaction region, and the operating software. During the course of the integration phase, the feasibility

of sharing these components in the integrated system will be determined. A common laser must serve the dual purpose of a pump source for the PPLN laser and a spark source for the LIBS measurement. The final sensor systems will be packaged for specific industrial or environmental applications and marketed by commercial partners.

ACCOMPLISHMENTS: For the IR spectrometer, most of the work effort focused on tuning the PPLN optical parametric oscillator (OPO), and assembling and demonstrating performance of the photoacoustic apparatus. The laser and the photoacoustic apparatus were integrated and a preliminary test of the system was made. The system was used to demonstrate coarsely-tuned photoacoustic scans over broad ranges in the C-H stretching region. For the PLIBS, using mercury as a surrogate species, a series of experiments designed to unravel the coupling effects of laser wavelengths, power density, and sample matrices in plasma initiation, formation, and signal detection was successfully completed. An aerosol generator capable of producing monodisperse and polydisperse particles and a gas permeation source for producing a known gas concentration, was designed, evaluated and is operational. In addition, a candidate laser source (the Lincoln Laboratory microchip laser) was identified and will be incorporated into an optimal system configuration.

TRANSITION: Two important collaborations are being established. The first involves work with a group (leaders in gas-phase photoacoustic spectroscopy for environmental and biological applications) from the Catholic University of Nijmegen in the Netherlands. The second involves Coherent Inc., a laser company that is developing a laboratory PPLN laser. These collaborations will accelerate this effort and open up a potential technology transfer path for a fieldable photoacoustic system.

PROJECT SUMMARY

PROJECT TITLE & ID: Detect and Identify Multiple Hazardous Air Pollutants (HAP) at Extended Distances; CP-1061

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Navy

LAB: Naval Research Laboratory - Washington, D.C.

PRINCIPAL INVESTIGATOR: Dr. Antonio Ting

FY 1999 FUNDS: $210K

OBJECTIVE: The objective of this project is to develop a new class of sources for active remote sensing of hazardous air pollutants (HAPs) using ultra broadband (UB) radiation, and techniques for their detection and identification. UB radiation can provide the necessary illumination required for active remote sensing to allow real-time ranging and identification of HAPs at extended distances.

BENEFIT: The application of UB radiation sources to remote sensing can lead to the identification, ranging, and detection of HAPs at extended distances through simultaneous spectral response from various HAPs. It will allow the tracking of major HAPs such as nitrogen oxides (NOx) and others (ClOx, SOx). It is also especially valuable during night time monitoring when sunlight is not available for conventional remote sensing methods. A system of active remote sensing using UB radiation will benefit efforts on continuous, real-time identification of HAPs that are of concern to Department of Defense (DoD).

TECHNICAL APPROACH AND RISKS: The mechanism for the generation of UB radiation is based on self-phase modulation of picosecond laser pulses in a nonlinear optical medium. Continuous UB radiation can be generated with extremely high efficiency and high average power by beating two laser beams with slightly different frequencies. The bandwidth of the radiation can extend from the optical to the Infrared (IR) regime. The source size of the UB radiation is extremely small, which allows for beaming the radiation over extended distances of several kilometers.

The generation of UB radiation in various nonlinear materials will be analyzed and evaluated using existing laser facilities at the Naval Research Laboratory (NRL). Lasers with optical and near-IR wavelengths will be used to generate UB. The conversion efficiency and bandwidth will be optimized by selecting the appropriate nonlinear medium. The quality of the UB radiation beam will be measured and its propagation in air characterized. The methodology and diagnostics necessary to evaluate the UB spectrum are based on hyperspectral imaging techniques that are presently being developed at NRL. Proof-of-principle experiments on active remote sensing will be performed, and data reduction techniques for analyzing complex spectral signatures will be studied.

ACCOMPLISHMENTS: Progress was made in four areas: (1) generation of UB radiation; (2) generation of a beatwave with a two-head laser; (3) laboratory experiments; and (4) publications. UB radiation (greater than 1.67 micron) was generated in fused silica optical fibers using beatwaves with fundamental frequency at 1.06, producing a spectrum that extends to more than 1.3 micron. More efficient UB radiation generation in longer wavelength regions is achieved by Raman shifting. A two-head laser with a stable continuous-wave (CW) oscillator was designed. Experiments were conducted to study the adsorption spectroscopic properties of atmospheric gases using broadband radiation. Modeling of the detection of chemical gases using the UB radiation was studied with a signal processing algorithm.

TRANSITION: The Transition Plan includes further development and demonstration within SERDP, including testing of the device in a field environment. Additional transition could occur in Small Business Innovation Research (SBIR) Phase I and II leading to Cooperative Research and Development Agreement (CRADA) Programs. This signal processing algorithm for identification of HAPs with the UB radiation was presented at an International Conference on Signal and Image Processing.

PROJECT SUMMARY

PROJECT TITLE & ID: Plasma-Assisted Catalytic Reduction of NOx; CP-1077

RESEARCH CATEGORY: 6.3 Advanced Development

LEAD AGENCY: U.S. Air Force

LAB: Air Force Research Laboratory - Tyndall Air Force Base

PRINCIPAL INVESTIGATOR: Dr. Joseph Wander

FY 1999 FUNDS: $405K

OBJECTIVE: The objective of this project is to further develop and optimize selective catalytic reduction (SCR) technology by using a non-thermal plasma to assist the catalytic destruction of nitrogen-species contained in gaseous emissions. It will extend bench-level observations of the cold-plasma-induced catalyzed chemistry of propene in simulated combustion-exhaust gases to include mixtures of fuel constituents common to JP-8 in actual combustion exhaust. Data will be used to design and assemble a pilot-scale device for treatment of exhaust from a diesel engine, and to project the cost/benefit of a full-scale control process.

BENEFITS: This project will provide a wider range of SCR catalysts with improved efficiency and durability, which when used in combination with a non-thermal plasma will eliminate some of the deficiencies of a purely catalytic approach. The specific benefits yielded will be:

1. Option to operate diesel-powered equipment at greater than 95 percent of baseline performance and fuel efficiency while emitting less than 10 percent of baseline pollutants.
2. Definitive determination about economic feasibility of catalytically augmenting plasma-induced chemical conversions.
3. Advancement of the state-of-the-art in SCR and other catalytic processes.

TECHNICAL APPROACH AND RISKS: In the SCR process, the destruction of partially oxidized nitrogen-based contaminants found in combustion-exhaust emissions proceeds by oxidation of N-species to NO_2 which are subsequently reduced to N_2 by a hydrocarbon. By choosing oxidation-catalyst components that pre-convert NO fully to NO_2, mechanically mixed with reduction-catalysts, catalysts previously regarded as inactive for NOx reduction have been shown to become efficient. Bench-scale studies on a simulated exhaust gas using propene as the reductant have accomplished a very efficient conversion of the mixture to N_2, CO_2, and water. The main technical challenge is maintaining high efficiency for NOx reduction when flow-rates are increased to pilot-scale (50 cfm), and when diesel fuel (and kerosene-like liquid hydrocarbons) is used as the reductant. The project will assemble and evaluate a pilot-scale NOx- and particulate- control device implementing the refined plasma-assisted SCR concept to treat exhaust flow from a Cummins diesel engine generator. Data from this pilot-scale test will support

estimates of the cost and performance of operating this technology as a full-scale emission control process and determine the extent of control that can be realized.

The focus will be to characterize and optimize the atomization and mixing of the liquid hydrocarbon reductant. Other options for optimizing the injection of the liquid hydrocarbon into the deNOx reactor will be investigated. A gas chromatograph system will be installed and used, together with a flame ionization detector and a Fourier Transform Infrared Spectrometer, to analyze the mixing and speciation of the fuel during the injection process. The NOx reduction efficiency will be characterized as a function of the engine power consumption, fuel consumption, and exhaust flow rate through the deNOx reactor.

ACCOMPLISHMENTS: A liquid hydrocarbon injector was installed in the exhaust pipe of the Cummins diesel engine generator. Two types of liquid hydrocarbons have been tested: kerosene and diesel fuel. The efficiencies of these hydrocarbons in the plasma-assisted catalysis process have been compared to that of propene. This work is the first test of plasma-assisted catalysis using the same diesel fuel for both the engine and the NOx control device. The preliminary data using diesel fuel, although very encouraging, indicated that it is not as good a reductant for NO2 as propene. These data have prompted a need to develop a predictive understanding of atomization, mixing processes and speciation for diesel and kerosene-like liquid fuels. Other options for optimizing the injection of diesel into the deNOx reactor will need to be investigated.

The effect of SO_2 in the diesel fuel on the NOx reduction activity was characterized to determine whether or not SO_2 is oxidized during the plasma-assisted catalytic reduction (PACR) process. Two conclusions appear to be emerging. First, there is no significant conversion of SO_2 into SO_3 during the PACR process. Second, the amount of hydrocarbon needed for PACR is driven by the conversion of NO into NO_2, rather than by the scavenging process that prevents the conversion of SO_2 into SO_3. The plasma/catalyst combination is highly effective in controlling NOx emissions even in the presence of large amounts of SO_2 in the exhaust. Plasma-assisted catalysis is more sulfur-tolerant than catalysis alone. This discovery is especially significant in light of the recent need to decrease the sulfur content of fuels to allow greater reduction of tailpipe emissions of NOx.

TRANSITION: The technology is expected to be ready for transition to an Environmental Security Technology Certification Program (ESTCP)-type demonstration and evaluation of a scaled-up prototype within two years. A commercial partner, Cummins Engine Co., is committed to deploying this technology as soon as it is technologically and economically viable.

PROJECT SUMMARY

PROJECT TITLE & ID: Enzymes for Degradation of Energetic Materials and Demilitarization of Explosives Stockpiles; CP-1078

RESEARCH CATEGORY: 6.1 Basic Research

LEAD AGENCY: Department of Energy

LAB: Pacific Northwest Laboratory

PRINCIPAL INVESTIGATOR: Dr. Manish Shah

FY 1999 FUNDS: $300K

OBJECTIVE: The objective of this project is to develop a safe, economical and environmentally sound process where biocatalysts (enzymes) could be used for degradation of energetic materials with an option of converting degradation by-products into value-added materials.

BENEFITS: If the proposed enzyme technology is successful, it will provide a low-cost alternative to incineration, Molten Salt, or Supercritical Water Oxidation (SCWO) processes. Special features of the proposed enzyme technology include: excellent kinetics, no special equipment requirements, enzyme effectiveness under diverse reaction conditions (i.e., solvents, high concentration of explosives, etc.), very high reactivity per unit weight of catalyst, simple operating process, remote locations accessible with enzyme spray, effectiveness at room temperature and atmospheric pressure, low operating and production costs, and potentially mobile systems would allow flexibility for demilitarization operations.

TECHNICAL APPROACH AND RISKS: The overall technical approach for the proposed research involves the transformation of munitions such as TNT, RDX, and HMX in different forms (compositions A, B, C, and D; H-6; Tritonal) to intermediate products using enzymes. The intermediate products, in some cases, are expected to have reduced or no toxicity and thus will be evaluated for their approval for disposal by the regulatory agencies. In other cases, the intermediates could be used as a feed stock in the chemical industry or destroyed to carbon dioxide and water using microbial and/or chemical processes. The toxicity of the intermediate products and final products will be evaluated.

The initial focus will be on the kinetics and mass transport issues involved in explosives (e.g., TNT) degradation by enzymes under heterogeneous conditions. A specific emphasis will be to understand the difference between the conversion of explosives by enzyme catalysis in a heterogeneous solid-liquid system compared to a normal heterogeneous catalytic aqueous system. Different combinations of enzymes, mediators, and reaction environments will be investigated.

ACCOMPLISHMENTS: In FY 1998, this project investigated the degradation kinetics of TNT above its solubility limit by various enzymes: ferredoxin NADP oxidoreductase and glutathione reductase from spinach, xanthine oxidase from buttermilk, and oxyrase enzymes from E.coli. The rate of transformation

of TNT was increased with the increase in enzyme or TNT concentration. The reduction of TNT lead to the formation and accumulation of one major intermediate which was identified as 4-hydroxylamino 2,6-dinitrotoluene. This intermediate has many potential industrial uses, and thus potentially may offer for economically viable recovery and re-use.

The ability of potassium superoxide to degrade explosive compounds such as RDX and HMX under aqueous conditions at room temperature and atmospheric pressure also was established. Similar to the enzymatic process, the superoxide radical-based process has excellent reaction rates, and works at room temperature and atmospheric pressure under aqueous conditions. However, the superoxide radicals are much smaller than the enzyme molecules and can thus penetrate the microstructure of plastic explosives much faster. In addition, the superoxide radical-based process generates reactive hydroxyl radicals, which could cause the destruction of other organic contaminants. The end products of the process are potassium ions and water, which are environmentally benign substances.

TRANSITION: A business relationship with an enzyme provider, Genencore International, was established. Additionally, a polymer scientist from Ethyl Corporation will perform a preliminary assessment of industrial applications of TNT-derived amines. One patent on the transformation of explosives by potassium superoxide was submitted and at least two manuscripts will be written before end of this fiscal year. The transition plan also includes a site demonstration with companies involved in demilitarization activities at the Naval Surface Warfare Center-Indian Head, the U.S. Army Defense Ammunition Center, and the Department of Energy Pantex Plant. Following the completion of SERDP funding, a transition to the Environmental Security Technology Certification Program (ESTCP) will be pursued. In an on-going effort to transfer this technology to the end user, the technical approach and preliminary results were presented at the GLOBAL DEMILITARIZATION conference. This project has also is receiving considerable coverage by the media (i.e., television, magazines, and journals).

PROJECT SUMMARY

PROJECT TITLE & ID: Hypergolic Non-Detonative Neutralization in Production and Demilitarization; CP-1079

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: Department of Energy

LAB: Sandia National Laboratory - New Mexico

PRINCIPAL INVESTIGATOR: Dr. Maher Tadros

FY 1999 FUNDS: $450K

OBJECTIVE: The objective of this program is to develop an innovative, alternative technology to replace open burn/open detonation (OB/OD) operations for the destruction and disposal of obsolete, excess, and off-spec energetic materials. The Department of Defense (DoD) faces many environmental and legal issues in the demilitarization of bulk energetic materials and assembled munitions. OB/OD is unacceptable in certain locations because of problems associated with noise and shock pollution, metal splatter, and lead emissions. The DoD stockpile of energetic materials that needs to be destroyed is about 700,000 tons, and this total increases at a rate of about 60,000 tons per year. The Department of Energy (DOE) also has a significant amount of weapons components which needs to be destroyed. If OB/OD is restricted or banned, then a new alternative technology must be ready to replace it. The project will develop environmentally conscious, high throughput, cost-effective, methods for disposal of energetic materials.

BENEFITS: This project will provide DoD and DOE with an alternative method for safe and effective disposal of energetic materials. These new methods will be based on chemical breakdown of the energetic materials without detonation and are expected to exhibit high throughput, cost effectiveness, and possibilities for reuse/reapplication of the byproducts.

TECHNICAL APPROACH AND RISKS: The initial focus will be to develop effective reagents and to understand the underlying chemistry for reacting the energetic materials with a hypergolic chemical, which neutralizes the energetic materials and precludes a detonation. The proposed approach uses organic amines, metal alkyls or amine-metal alkyl adducts to neutralize explosives. These have been shown to react hypergolically with Trinitrotoluene (TNT), Composition B, and RDX.

A few grams of these chemicals have been shown to be capable of initiating the autocatalytic self-consumption of up to 7 kg of TNT and Composition B in field tests. If larger quantities of the chemical initiators are used, or the initiators are diluted with solvents, the reaction is not hypergolic; instead, a tarry residue is formed which has been shown to be non-detonable. Detonation has never occurred in numerous field tests in which the autocatalytic self consumption of the explosive has been initiated with the above chemicals, even though the explosive was confined during the decomposition process.

The chemistry related to the interaction of organic amines and metal alkyls with explosives is poorly understood and one objective of this program is to further elucidate the reaction mechanisms. Two approaches will be used for the pre-treatment of explosives: (1) relatively low temperature, controlled exothermic reactions in a liquid-phase environment, and (2) solid-state, controlled hypergolic reactions. Overall these approaches have great potential in the pre-treatment of explosives to produce a non-detonable product for reuse or final treatment in a steam reforming reactor. However, it will be necessary to study the mechanisms and kinetics of the chemical reactions to enable development of a reliable technology applicable to a wide range of energetic materials.

The project will focus on the identification of the reaction products, their toxicity and potential reuse. Thin layer chromatography, high pressure liquid chromatography, infrared, nuclear magnetic resonance, mass spectroscopy and if necessary preparative chromatographic methods will be employed. The products will be purified to facilitate their identification, and reactions with simpler amines such as cyclohexylamine and ethylenediamine will also be conducted to eliminate the potential for polymerization which complicates product identification.

ACCOMPLISHMENTS: In FY98, Proof-of-concept experiments were completed using differential thermal analysis, adiabatic calorimetry, and thermogravimetric analysis to identify reagents for the deactivation of TNT. Ethanolamine, and diethylenetriamine exhibit controlled exothermic reactions with TNT at room temperature in a variety of solvents and in the solid state. Diethylenetriamine reacts exothermically but in a safe and controlled manner with RDX in the temperature range of 90-140C. The energy release from the reaction with TNT is used to initiate the reaction with RDX. This enables deactivation of the explosive material known as Composition B which is composed of 40%TNT, 59%RDX and 1% wax. Product identification by IR, multielement NMR, GC, and elemental analysis was initiated.

TRANSITION: The technology developed under this project will be made available to users within DoD and DOE, including partners for prior collaborative efforts. Conventional chemical processing equipment is adequate for full scale implementation of this technology.

PROJECT SUMMARY

PROJECT TITLE & ID: Optimization of an Innovative Biofiltration System as a VOC Control Technology for Aircraft Painting Facilities; CP-1104

RESEARCH CATEGORY: 6.2 Applied Research

LEAD ORGANIZATION: U.S. Air Force

LAB: Air Force Research Laboratory

PRINCIPAL INVESTIGATOR: Dr. Kerry Kinney - University of Texas at Austin

FY 1999 FUNDS: $87K

OBJECTIVE: Until alternative coating materials and depainting operations become available, treatment of fugitive Volatile Organic Compound (VOC) contaminant releases during application or removal of coatings is necessary to maintain compliance with the Clean Air Act Amendments of 1990. Currently available VOC emissions control technologies are costly at the high volumetric flow rates and low contaminant concentrations associated with the ventilation of aircraft hangars.

This project will develop an innovative, high flow-rate biofiltration method for treating VOC-laden air emissions. Biofiltration of painting off-gas streams currently is limited, not because of insurmountable technical problems but simply because current systems have not been designed to handle the operating conditions typical at these facilities. Innovative design features and biofilter configurations will be investigated, tested, and applied to an actual Air Force paint spray booth.

BENEFITS: The project will provide a stable biofiltration system for paint spray booth applications that operate intermittently and emit varying quantities of VOCs. Typical biofilter problems such as long acclimation times, slow response to load changes, and biomass clogging will be overcome. The innovative biofiltration process developed by this project will, therefore, be suitable for venting of aircraft hangars during application or removal of coatings. It has the added advantages of operating at ambient temperatures and minimizing the generation of secondary wastes.

TECHNICAL APPROACH AND RISKS: The following innovative design features will be investigated for their ability to improve biofilter performance for paint spray booth applications: (1) a recirculating inoculation method to shorten the bioreactor start-up period; (2) directionally-switching operation to improve biomass distribution and prevent clogging; (3) slip-stream feed to maintain high biomass activities during paint spray booth shutdown periods; and (4) an aerosol nutrient delivery system to efficiently deliver nutrients and moisture to the biofilm. Since bioreactor performance is strongly influenced by the contaminants being treated, the effectiveness of each design modification will be determined under single (e.g., ethyl acetate) as well as multiple [e.g. methyl ethyl ketone (MEK), methyl isobutyl ketone (MIBK), toluene] contaminant conditions representative of paint spray emissions. Previous studies have shown that the degradation of MIBK, in particular, is adversely affected by the presence of MEK. Other risks are

whether stable and effective, long-term operation can be achieved while operating in a directionally-switching mode and using an aerosol nutrient/moisture delivery system.

The first part of this work will focus on constructing experimental reactors and investigating and optimizing the recirculating inoculation method and the directionally-switching design modification through a series of laboratory-scale experiments. A total of three bioreactors packed with artificial media will be utilized in this study, two laboratory-scale units and one pilot-scale unit. The modified pilot-scale bioreactor will be tested at an actual paint spray booth facility located at Kelly Air Force Base in San Antonio, Texas.

ACCOMPLISHMENTS: In FY 1998, two stainless-steel, laboratory-scale bioreactors were constructed and are currently in operation treating toluene-contaminated air. To provide a basis for comparing a unidirectional and a directionally-switching biofilter, one of the bioreactors is operating in a unidirectional mode and one is operating in directionally-switching mode. The research team has also developed and tested a new method for assessing biomass activity in the biofilter. In this method, a redox dye, 2-(p-iodophenyl)-3-(p-nitrophenyl)-5-phenyltetrazolium chloride (INT), is used to detect metabolically active biomass in a sample of biofilm from the biofilter. Preliminary results indicate that the INT method is a promising tool to determine the microbial activity of the biomass. To evaluate biofilter operation, it is essential to be able to determine the distribution of active biomass throughout the biofilter and to be able to distinguish between active and inactive biomass. The INT active biomass method should allow such a determination to be made. Results of start-up experiments indicate that the bioreactor acclimation period is very sensitive to the amount of nitrogen initially available in the system and the initial VOC contaminant feed supply. It appears that presoaking the packing media in a nitrogen rich solution prior to start up is essential to shorten the acclimation period and that unsteady inlet contaminant feed conditions detrimentally affect biofilm development. Toluene-, ethyl acetate- and MEK-degrading microbial cultures have been isolated and developed. The toluene degrading culture has been used to inoculate the two laboratory bioreactors. The ethyl acetate and methyl ethyl ketone degrading cultures will be used to inoculate the bioreactors when a mixture of paint spray contaminants (e.g., toluene, ethyl acetate and MEK) are fed to each bioreactor. Experiments have begun to optimize the switching frequency in the directionally switching biofilter.

TRANSITION: The primary users of the biofiltration technology will be Department of Defense paint spray booth facilities; however, the technology also will be widely applicable to the private sector. Research results will be published in forums that reach a large audience of professionals in air pollution control including the Annual Meeting of Air and Waste Management Association. A web site also will be dedicated to the proposed research and will include brief statements related to research objectives and interim results.

PROJECT SUMMARY

PROJECT TITLE & ID: Membrane-Mediated Extraction and Biotreatment of VOCs; CP-1105

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: Environmental Protection Agency

LAB: National Risk Management Research Lab

PRINCIPAL INVESTIGATOR: Mr. Norman Kaplan

FY 1999 FUNDS: $570K

OBJECTIVE: Until alternative coating materials and depainting operations become available, treatment of fugitive volatile organic compound (VOC) contaminant releases during application or removal of aircraft coatings is necessary to maintain compliance with the Clean Air Act Amendments of 1990. Currently available VOC emissions control technologies are costly at the high volumetric flow rates and low contaminant concentrations associated with ventilation of paint spray booths.

In conjunction with the recently developed partitioned recirculation flow reduction technique, this project will develop a novel Membrane BioTreatment (MBT) system, which combines a first-stage microporous, polypropylene, hollow-fiber membranes unit to extract and concentrate VOC contaminants into a low-volatility organic stripping fluid, with a similar second-stage membrane unit in which the VOCs are extracted into a nutrient medium for biotreatment. VOC contaminants are completely metabolized by the microorganisms. Independent operation and optimization of each stage of the process will accommodate intermittent painting operations and reduce equipment size.

BENEFITS: This proposed treatment will minimize the volumetric flow of contaminated air to be treated, concentrate the VOCs to reduce the size and cost of control equipment, and then completely destroy the VOCs without producing a secondary waste stream. These advantages make this VOC treatment a viable option over a broad range of spray booth sizes.

TECHNICAL APPROACH AND RISKS: The work will be conducted in two phases, with appropriate decision points throughout the program. In Phase I, process streams will be characterized at the bench scale to show technical feasibility using simulated streams composed of one or more organic constituents found in aircraft coatings and by using representative exhaust from a laboratory spray booth for aircraft topcoats. Mass transfer coefficients will be evaluated using octanol, sunflower seed oil, and mineral oil as stripping fluids for at least one organic contaminant. The goals are to identify the most effective stripping fluid and to establish a mathematical relationship between stripping fluid flow, contact time, and VOC removal efficiency. A series of experiments also will be conducted to determine the stripping efficiency of a bench-scale biotreatment module, with and without biofilms present, to account for the additional resistance added by the biofilm during degradation of the VOC contaminants. Mass transfer

rates, biodegradation rates, flow rates, and modular equipment sizes will be evaluated prior to design and laboratory testing of an integrated pilot scale system. A pilot MBT system will be tested in Environmental Protection Agency's (EPA) Coatings Laboratory using military paints.

In Phase II, the pilot MBT system will be evaluated at Tyndall Air Force Base to determine longer-term performance of microbes and hardware and to develop and validate scale-up parameters. Microbe performance with VOC primers and topcoats will be evaluated, first individually and then under cycling operations to assess the ability of the system to respond to rapidly changing feedstock. Analysis will include on-line Gas Chromatography (GC), as well as Gas Chromatography/Mass Spectrometry (GC/MS) analysis of batch samples, to determine removal and degradation efficiencies of specific VOCs. Upon successful completion, the Air Force Research Laboratory/MLQ will develop application criteria and identify installations for further full-scale testing.

ACCOMPLISHMENTS: An evaluation of stripping fluids was conducted in FY 1998 using silicone oil, octanol and canola oil. While much of the previous data were collected using octanol, it appears that canola oil is the best candidate for future use because of its low cost, low viscosity and equivalent partitioning coefficient. Initial testing will be done with octanol which is a pure compound. Bench-scale extraction and treatment modules have been set up for evaluating VOC removal from the air stream and biodegradation of the VOCs from the oil. Biofilm retention and longevity are being evaluated in a flat-plate biomembrane system to determine proper system operating conditions to maintain a vigorous biofilm culture. Acetone, MEK and m-xylene degraders have been reestablished and are being used to retest degradation rates. Three-component VOC mixtures will be evaluated followed by typical VOC mixtures from aircraft paint booth exhausts.

TRANSITION: If it is determined that the technology is economically feasible, the Air Force will identify Department of Defense (DoD) sites that are potentially well-suited to adopt this technology. The sites may include both aircraft and ground equipment painting facilities. Simultaneously, EPA will develop a plan to transfer the technology to the installations identified. The sites will be provided with a jointly developed technology package. The intent is to select a full-scale demonstration site and propose a follow-on project. The technology transfer plan will include developing printed materials for direct mailing, papers, and presentations for symposia. Negotiations are underway with membrane manufacturers for the procurement of pilot-scale extraction and biotreatment modules. The two most likely vendors are Celgard Inc. (Hoescht-Celanese) and Bend Research Inc. Both have expressed an interest and willingness to participate in this project.

PROJECT SUMMARY

PROJECT TITLE & ID: Characterization of Particulate Emission: Size Characterization and Chemical Speciation; CP-1106

RESEARCH CATEGORY: 6.2 Applied Research

LEAD ORGANIZATION: U.S. Air Force

LAB: Air Force Research Laboratory

PRINCIPAL INVESTIGATOR: Dr. Adel Sarofim - University of Utah

FY 1999 FUNDS: $989K

OBJECTIVE: The objectives of this project are to develop advanced methods for the measurement of the size distribution and composition of particulate matter (PM) emitted from mobile and stationary sources and provide the Department of Defense (DoD) with the tools needed to characterize and control the emissions from DoD facilities. The feasibility of using advanced analytical measurements to characterize the chemical composition and size of particulate emissions from a diverse range of sources operated by the DoD will be determined. The data obtained during the evaluation of the instruments will provide a measure of the relative importance of different DoD sources and will be useful for guiding the strategies for controlling the emissions from DoD facilities. The cost effectiveness of different measurement methods will be assessed and recommendations made for the best protocols for measurement of fine particle emissions.

BENEFITS: The project will provide DoD with rapid measurement procedures for organic and inorganic emissions at greatly reduced cost per analysis as well as detailed chemical compositions of major source categories by size. Assessments will be provided of the relative cost of alternative measurement strategies, ease of use, potential for use for feedback control, reliability, and speed.

TECHNICAL APPROACH AND RISKS: Two innovative techniques for rapid measurement of fine particles will be used in combination with a dilution sampler. The first is an aerosol time of flight mass spectrometer (ATOFMS) that measures the size and composition of individual articles. The second is a photoelectric aerosol sampler (PAS) which, in combination with a photoacoustic elemental detector (PED) for carbon, provides rapid measurement of the polycyclic aromatic hydrocarbon (PAH)-laden carbonaceous particles which dominate the emissions from combustion sources. The approach is to apply these devices in parallel with more conventional measurement techniques to establish their validity for characterizing the particle emissions from DoD sources. Multiorifice impactors (MOI) combined with chemical analysis will be used to obtain chemical characterization sufficiently detailed to close material balances on the emissions. Optical particle counters (OPC) and differential mobility analyzers (DMA) will be used to obtain detailed size distributions in order to calibrate the ATOFMS and PAS.

The first task will be to calibrate these methods in the laboratory. This will be followed by the evaluation of the use of the techniques for the measurement of emissions of aircraft engines and aircraft ground equipment at Hill Air Force Base and at the North Island Naval Air Depot. The techniques will be used finally for the characterization of open sources such as munitions disposal and dust from bombing ranges. The second task will be to enhance the measurement capabilities and compare them with other techniques. For example, the ATOFMS is now capable of determining particle sizes to 0.1 micron. The capability of obtaining smaller particle sizes will be investigated. The techniques will be used for the characterization of open sources such as munitions disposal and dust from bombing ranges.

ACCOMPLISHMENTS: In FY 1998, a survey of equipment was completed including compilation of fuel usage data for Hill AFB. From this survey, the type of fuels and vehicles that will be tested using the ATOFMS in parallel with the integrated sampling and characterization train were selected. Preliminary testing of the PAS began. Two ATOFMS were set up with a Caltech sampling system to test 13 gasoline- and diesel-powered vehicles and results are being analyzed.

TRANSITION: At the end of the source test program, the techniques used in the advanced source test system will be evaluated in terms of ease of use, time of sampling to obtain data, time to analyze data, and capital and operating costs. Negotiations are in progress to produce a commercial version of the ATOFMS. The current project will have developed the calibrations necessary for producing quantitative emission measurements on DoD sources as well as provided a measure of the cost effectiveness of using this technology. During the course of the project, personnel from Hill Air Force Base and the Air Force Research Laboratory will evaluate the ease of transfer of the instruments to the field.

PROJECT SUMMARY

PROJECT TITLE & ID: Electrochemical Advanced Oxidation Process for Shipboard Final Purification of Filtered Black Water, Gray Water, and Bilge Water; CP-1107

RESEARCH CATEGORY: 6.2 Applied Research

LEAD ORGANIZATION: U.S. Navy

LAB: Naval Surface Warfare Center

PRINCIPAL INVESTIGATOR: Dr. Oleh Weres - Sonoma Research Company

FY 1999 FUNDS: $202K

OBJECTIVE: The overall objective of this project is to advance development of an electrochemical Advanced Oxidation Process (AOP) which will be used as a final polishing step following membrane filtration of shipboard wastewater. To comply with International Maritime Organizations Marine Pollution Convention (MARPOL) Annex V and other environmental regulations, U.S. Navy vessels require compact, energy efficient water purification technology which will allow most of the wastewaters produced on board (bilge, gray, black, etc.) to be discharged overboard following purification. In addition, military bases and private industry generate wastewater in machine shops which must be purified before discharge to sewers. Membrane filtration does not achieve the degree of purification required, and a final "polishing" process is needed prior to discharge overboard. The specific objectives include producing AOP electrodes with improved service life and improved performance at low substrate concentrations, developing methods for reprocessing the electrodes, and identifying optimal operating conditions for the AOP.

BENEFITS: Once the practical feasibility of this technology has been demonstrated, the U.S. Navy will be able to decide what combination of shipboard wastewater treatment technologies to plan for. In combination with improved membrane filtration technology, electrochemical AOP will allow existing ships to be retrofitted for compliance with MARPOL Annex V and other regulations. Estimated cost savings over 20 years are $1.49 billion (estimate of cost to off-load untreated wastewaters). Electrochemical AOP will find broad military and industrial applications, wherever moderate concentrations of contaminants need to be removed from water at moderate cost.

TECHNICAL APPROACH AND RISKS: Existing equipment for producing small test electrodes in the laboratory will be upgraded. An apparatus permitting long-term testing of the electrodes will be developed, and a correlation of service life vs. current density will be determined. Tests will be developed to evaluate the kinetics of different oxidation mechanisms for several substrates. X-ray diffraction, scanning electron microscopy, and specialized surface analyses will be used to characterize the crystal structure, surface morphology, and surface composition of the electrodes.

Fiber made of the alloy Ti-6Al-4V (aerospace titanium) will be procured and evaluated for service as an electrode substrate. This alloy is expected to decrease the brittleness of the porous anodes produced, and

thereby allow reprocessing of used-up electrodes at a fraction of replacement cost. A standardized test of brittleness of the coated Ti-fibers will be developed.

The precoating process, which is necessary to provide a useful electrode service life, will be optimized to eliminate the use of flammable organic solvents, and to decrease seepage of the precoating material into the electrocatalytic oxide coat. Also, the method of application of the oxide coat will be optimized to provide better surface coverage and better block access of electrolyte (that is, the water being treated) to the precoat and underlying metal, thereby improving the efficiency of the electrode and increasing its service life.

ACCOMPLISHMENTS: In FY98, values of current yield in the 30-55% range using precoated anodes were achieved. The improved production method and sealing coat that allowed this breakthrough also eliminated the need for high temperature annealing of the electrodes, thereby simplifying and accelerating the production of test and full-sized electrodes. Mini-plate test anodes were developed and put into use. Attempts were made to determine current yield of hydroxyl ion at the anode by measuring the amount of oxygen produced. While this effort has not yet achieved its goal to allow direct and quick measurement of the current yield of the anode without using Chemical Oxygen Demand (COD) tubes, it indicated that the reaction at the cathode and the interaction of anode with cathode have a major effect upon current yield attained.

Experimental observations lead to the hypothesis that the one-electron reduction of oxygen to superoxide at the cathode sets-up a parasitic reaction cycle. The gap between anode and cathode in the optimized electrolytic cells is small and mass transfer is quite good, therefore, the superoxide produced at the cathode is able to reach the anode where it is readily reoxidized to oxygen. In effect, a short-circuit exists between cathode and anode, and part of the current flows through the cell producing no net reaction. The realization that processes at the cathode and interaction between cathode and anode can have a large effect upon current yield opens new possibilities for improving overall performance of the electrolytic cell.

The first complete set of sample anodes at various stages of the coating process have been analyzed utilizing X-ray diffraction and several techniques of surface analysis. The results of surface analysis indicate that the morphology and thickness of the resultant precoat vary tremendously from fiber-to-fiber. Bringing this subtle processing variable under control should enable better control the morphology of the anodes produced, thereby allowing improved current yield and service life.

TRANSITION: Interested potential users have been identified, including: the Naval Facilities Engineering Center, the Carderock Naval Surface Warfare Center, Eaton Corporation, and Showa Engineering Co. of Tokyo, Japan. *Chemical Engineering* magazine twice described this technology, eliciting 130 requests for information. The prototype water treatment unit will very likely be carried forward to eventual commercialization.

PROJECT SUMMARY

PROJECT TITLE & ID: Novel Nonporous Fouling - Resistant Composite Nanofiltration Membranes and Membrane Separation Systems for Wastewater Treatment; CP-1108

RESEARCH CATEGORY: 6.2 Applied Research

LEAD ORGANIZATION: U.S. Navy

LAB: Naval Surface Warfare Center

PRINCIPAL INVESTIGATOR: Dr. Benny Freeman - North Carolina State University

FY 1999 FUNDS: $490K

OBJECTIVE: Fouling associated with currently available membranes is the principal problem inhibiting widespread adoption of nanofiltration/ultrafiltration to treat shipboard wastewater to allow the Navy to meet current future overboard discharge limits. All current nanofiltration/ultrafiltration membranes are finely porous and are subject to surface or internal fouling by particulates, resulting in a dramatic decline in the water flux. The objective of this project is to develop a shipboard wastewater treatment system based on a novel type of fouling-resistant, composite-membrane module. The composite membrane will consist of an ultrathin (0.2-0.5 micrometer), nonporous, highly water-permeable, rubbery, block copolymer layer coated on to a conventional, microporous ultrafiltration or nanofiltration membrane for support. This coating layer provides fouling resistance without significantly reducing the water flux.

BENEFITS: Novel, low-fouling membranes for graywater and bilgewater treatment would offer longer service life and less frequent cleaning. When housed in high performance modules, these would provide a compact, reliable, economical shipboard wastewater treatment facility to enable the Navy to meet current and anticipated wastewater purification targets. This technology will be widely applicable to Navy and civilian ships and to onshore treatment of highly fouling waters.

TECHNICAL APPROACH AND RISKS: Three candidate materials have been developed under earlier Office of Naval Research grants. In this project, development of these membranes will be completed and a systematic series of new materials will be synthesized and characterized. The properties of these new heterophase block copolymer membrane materials will be tailored to provide better fouling resistance than conventional membranes while maintaining or improving the flux/selectivity combinations relative to currently available materials. These materials will be based on aromatic polyamide hard blocks with either hydrophilic ether groups as the soft, water-permeable block or water-soluble aromatic polyamides as the hydrophilic blocks. This research program will characterize the physical, chemical, and morphological structure of these materials as well as their water permeation, rejection, and fouling properties to develop systematic structure/property relations to guide the preparation of a new generation of advanced high performance materials for shipboard wastewater treatment. The best membrane materials will be selected for scale-up, first to bench-scale and then to industrial-scale membrane modules for evaluation in a pilot-scale system.

The risks associated with this approach include difficulties that might be encountered in the preparation of new materials, the unknown ability of these materials to be formed into thin film composite membranes, the durability of these materials in long term tests, and the ability of the materials to withstand cleaning protocols which might be used to regenerate their properties after extended use.

ACCOMPLISHMENTS: In FY 1998, efforts focused on: (1) optimizing polymerization preparation methods and characterizing new coating materials; (2) developing membrane coating methodology; and (3) developing bench-scale modules. Commercial polymers and previously developed experimental polymers (Pebax, Nafion, and PFOMA-b-PDMAEMA) were characterized for water uptake, permeability, and fouling properties. Three new families of heterophase polymers were also synthesized: poly(ethylene oxide)-b-poly(p-benzamide) block copolymers; random and block copolymers based on the polyisophthalamide of 4,4'-methylenedianiline, (MDA-I) or of 2,5-diaminobenzenesulfonic acid, (PPDS); and poly (sulfo-m-phenyleneisophthalamide)-b-poly(m-phenyleneisophthalamide) block and random copolymers. Interfacial polymerization routes for synthesis of these block copolymers were faster (for screening purposes) than the traditional solution polymerization route due to less stringent monomer purification requirements. High flux, thin- film composite membranes were prepared, which will be tested when fabrication of bench-scale modules is complete.

TRANSITION: Collaboration will occur with Hydranautics Inc., San Diego, CA in the module preparation work in the final phase of the project. Hydranautics is a major producer of membrane water treatment modules in the U.S. and would be a logical commercialization partner to introduce this technology to the water treatment market.

PROJECT SUMMARY

PROJECT TITLE & ID: Development of a Catalyzed Ceramic Filter for Combined PM2.5 Removal and VOC and CO Oxidation; CP-1120

RESEARCH CATEGORY: 6.2 Applied Research

LEAD ORGANIZATION: U.S. Air Force

LAB/PERFORMER: CeraMem Corporation

PRINCIPAL INVESTIGATOR: Dr. Bruce Bishop

FY 1999 FUNDS: $262K

OBJECTIVE: The project's objective is to develop high performance filters applicable to the treatment of a number of DoD combustion gas streams. The filters will be highly compact, ceramic-membrane-coated, silicon carbide (SiC) monolith filters, which can be additionally coated with non-selective catalysts to achieve simultaneous removal of particulate matter while oxidizing vapor-phase volatile organic compounds (VOCs) and carbon monoxide (CO). The oxidation catalysts can also result in "passive" regeneration of soot to allow extended continuous operation.

BENEFITS: The DoD and DOE need new, cost-effective technologies to comply with the proposed, more stringent EPA standards for particulate matter as small as 2.5 microns (PM2.5) for sources such as jet-engine test cells (JETCs), diesel engines, generators, incinerators and steam boilers. If effective, the proposed filters will bring a unique combination of particulate removal capability (PM2.5 compliant), temperature resistance (900°C), and compactness (more than any other competitive filter) with the ability to be catalyzed for simultaneous collection and destruction of organic particulate and gaseous pollutants.

TECHNICAL APPROACH AND RISKS: The project will be carried out in three phases to develop high performance filters to control pollutant emissions from combustion gas sources: (1) Development and characterization of SiC monolith filters which will be operated in various modes, either for high-efficiency full-particulate-retention, passive catalytic regeneration or backpulse regeneration; (2) Scale-up of filter construction, catalyst impregnation methods, and testing; and (3) Single-filter, slip-stream tests at selected DoD user sites.

Three types of filter will be tested. The first type is a backpulse-regenerable, compact, ceramic filter capable of reducing particulate concentrations to PM2.5 compliant levels. The second type is similar to the first except that an oxidation catalyst will be deposited on and within the pore structure in order to simultaneously remove gaseous pollutants such as VOCs and carbon monoxide (CO). The third filter type will be similar to the first except that an oxidation catalyst for removal of organic particulate will be deposited on the surface of the membrane coating. This catalyst will passively regenerate the filter by oxidizing the filtered particulates, thereby eliminating the need for backpulsing. After the development

of prototype filters, field tests will be conducted to demonstrate the efficacy of removing particulates, VOCs and CO from selected gas streams. Ceramem will provide two existing, highly instrumented, high-temperature-duty, gas filter pilot plants for these field tests.

ACCOMPLISHMENTS: This is a FY 1999 New Start.

TRANSITION: The proposed ceramic filter technology will yield a Best Available Control Technology (BACT) for specific operational niches such as confined spaces, high temperature duty, and simultaneous removal of particulates, VOCs and CO, with the potential for additional downstream NOx destruction. The transition plan includes licensing the technology to filter manufacturers.

PROJECT SUMMARY

PROJECT TITLE & ID: Reduction of Particulate Emissions from Jet Engine Test Cells Using an Annular After-Reactor; CP-1126

RESEARCH CATEGORY: 6.2 Applied Research

LEAD ORGANIZATION: U.S. Navy

LAB: Naval Facilities Engineering Service Center

PRINCIPAL INVESTIGATOR: Dr. Norman L. Helgeson, Naval Facilities Engineering Service Center

FY 1999 FUNDS: $255K

OBJECTIVE: This project will develop a prototype Annular After Reactor (AAR) jet-engine attachment to reduce particle emissions from jet engine test cells (JETCs). The AAR, positioned in the flow path of the jet engine exhaust tube, is simply a hollow pipe which delays mixing of exhaust gases with the surrounding air stream for a sufficiently long residence time to permit incineration of the PM (up to 90%) with minimum pressure drop. With slight modification, the system may also be adapted for removal of NOx, CO and unburned hydrocarbons.

BENEFITS: The DoD and DOE need new, cost-effective technologies to comply with the proposed, more stringent EPA National Ambient Air Quality Standards (NAAQS) for particulate matter below 2.5 microns (PM2.5) for sources such as JETCs, and future National Emission Standards for Hazardous Air Pollutants (NESHAP) specific to JETC emissions. If demonstrated to be effective, the AAR is a minimum-capital-cost, minimum-operating cost approach for reducing PM emissions from JETCs.

TECHNICAL APPROACH AND RISKS: The project will be carried out in four phases: (1) analytical and computer studies to refine the basic AAR fluid dynamics model and establish design criteria for field tests; (2) intermediate-scale field testing to complete the AR design; (3) full-scale AR system fabrication and field testing at a California Naval Air Station; and (4) data reduction and analysis to provide the recommended AR system for PM reduction. The most challenging technical aspect of this study will be the efficient and rapid mixing, and the combustion, of the injected natural gas within the AAR to achieve a proper temperature profile. Excessive pressure drops are expected to be eliminated by using a jet exhaust diffuser on the inlet to the AAR. The challenges of non-steady operating conditions will be addressed by using a feed-forward control system to make required AAR adjustments in concert with programmed changes in engine operating conditions. By maintaining the temperature of the exhaust gases within the AAR at 2000F, it is believed the generation of nitrogen oxides within the AAR will be insignificant.

ACCOMPLISHMENTS: This is a FY 1999 New Start.

TRANSITION: The Army, Navy and Air Force have each expressed an interest in application of this proposed technology if it is demonstrated to be effective. In addition to JETCs, this technology has potential to transition to other stationary and mobile sources of combustion emissions.

PROJECT SUMMARY

PROJECT TITLE & ID: Thermal Actively Controlled Sludge Treatment; CP-1132

RESEARCH CATEGORY: 6.3 Advanced Research

LEAD ORGANIZATION: U.S. Navy

LAB: Naval Air Warfare Center Weapons Division, China Lake

PRINCIPAL INVESTIGATOR: Dr. Klaus C. Schadow, Naval Air Warfare Center Weapons Division

FY 1999 FUNDS: $500K

OBJECTIVE: This project proposes a system that addresses the sludge disposal problem onboard ships by using a unique, highly compact and high performance combustion process. The project's objective is to develop a two-stage incineration process comprising: (1) a primary vortex containment combustion (VCC) process, which also separates and retains particulates; (2) a self-propagating, high-temperature synthesis (SHS) thermal processing and encapsulation process for treatment of resultant ash; and (3) an actively controlled and monitored after-burner (AB) process for emissions reduction. The process can be automated and integrated into a comprehensive, continuously operated, oily water treatment system.

BENEFITS: The DoD currently makes wide use of oil/water separators (OWS) to remove oil from a variety of aqueous waste streams prior to discharge. On-site or shipboard methods to treat or reduce the volume of accumulated sludges generated by these OWSs are required to eliminate sludge transportation costs for offsite disposal, to reduce downtime for maintenance, and to increase separator efficiency. The Navy is spending about $24M per year to treat 1 billion gallons of bilge oil per year. This treatment includes storage, off-loading, on-shore treatment, transportation, and off-site disposal. This technology could significantly reduce cost by on-site disposal, either on shore facilities or, for larger vessels, on-board ship. Other advantages of on-site disposal include increasing costs of off-site disposal, reducing assumed liability of third party disposal, eliminating waste handling and transportation, and avoiding costs for improper field disposal.

TECHNICAL APPROACH AND RISKS: The technical approach builds on the compact, closed-loop-controlled waste incinerator for blackwater successfully developed in previous SERDP projects CP-034 and CP-887 (see this Appendix). It consists of six development phases: (1) fundamental laboratory-scale studies (injection, swirl design, flame stability, laser diagnostics, modeling, ash treatment) on surrogate sludge waste mixtures; (2) VCC and AB integration schemes; (3) conceptual design; (4) scale-up and testing of practical embodiments under full-scale conditions; (5) integration of monitoring and automatic active control schemes; and (6) testing requirements definition for future transition to a demonstration/ validation program.

ACCOMPLISHMENTS: This is a FY 1999 New Start.

TRANSITION: The user community will be involved throughout the development of the proposed work. There have been discussions with Navy organizations, and the Army and Air Force have also expressed interest in the new sludge treatment system for potential application to a Deployable Waste Disposal System.

APPENDIX C
Conservation Project Summaries

PROJECT SUMMARY

PROJECT TITLE & ID: Whale Monitoring Using IUSS; CS-48

RESEARCH CATEGORY: 6.3 Advanced Development

LEAD AGENCY: U.S. Navy

LAB: Office of Naval Research - Arlington, VA

PRINCIPAL INVESTIGATOR: Dr. Robert C. Gisiner

FY 1998 COMPLETED PROJECT

OBJECTIVE: The goals of this project were to apply U.S. Navy Integrated Undersea Surveillance System (IUSS) capabilities to monitor various species of living resources, and to contribute to the conservation and regulatory compliance goals of the U.S. Navy. The IUSS provides a unique resource to monitor the presence, distribution, movements, and relative abundance of several endangered and protected marine mammal stocks, with greatest emphasis on the large baleen whales.

BENEFIT: The research enhanced the U.S. Navy's ability to assess and mitigate potential impacts of its activities on marine mammals. Without the data supplied by IUSS, critical Navy activities are at serious risk of being limited due to uncertainty about the potential for environmental impact. The project greatly improves National Oceanic and Atmospheric Administration's (NOAA) ability to carry out its mission of conserving and managing marine mammal stocks by greatly expanding the database on little-known, wide ranging, pelagic, marine mammals like the large whales. This project also will help calibrate and expand the "tool kit" of survey methods currently used by NOAA to estimate marine mammal stocks that were virtually unsurveyable.

ACCOMPLISHMENTS: In FY 1998, the three primary tasks were completed and final results published: 1) the integration of IUSS data into Navy/NOAA databases used in assessing potential impacts of human activities on endangered and protected marine mammals; 2) the creation of unclassified IUSS data access for use in furthering research, resource management, and education; and 3) a comparative assessment of IUSS capabilities with other marine mammal monitoring and assessment tools. A close working relationship was developed with NOAA, as an essential goal of the project in consideration of NOAA's role as the management and regulatory agency for protected marine life.

TRANSITION: This project provided support for the Navy's marine mammal compliance program. A three year archive of Northeast Pacific data was incorporated into the Navy environmental compliance database. Collectively the marine mammal data sets form the basis for a major FY 99 National Oceanographic Partnership Program to be transitioned to an operational Navy database for fleet use in FY00. Data on the first-order effects of Navy operations on marine mammals are now available for NEPA analysis and for planning future Naval exercises. The National Marine Fishery Service has adopted this acoustic census capability. The SOSUS test bed and multi-array IUSS data are available for biological and geophysical ocean science use.

PROJECT SUMMARY

PROJECT TITLE & ID: Strategic Natural Resources Management Methodology; CS-373

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: Department of Energy

LAB: Argonne National Laboratory

PRINCIPAL INVESTIGATOR: Ms. Pamela Sydelko

FY 1998 COMPLETED PROJECT

OBJECTIVE: There are two objectives for enhancing the Integrated Dynamic Landscape Analysis and Modeling System(IDLAMS) framework:

1. Enhance the IDLAMS framework by conducting a test using a case study approach at the IDLAMS user site by leveraging with object-oriented initiatives within the Dynamic Integrated Architecture System (DIAS) approach and technology.

2. Develop IDLAMS links with industry GIS data and technology. This objective increases the level of use of IDLAMS and advance technology demonstration at the user site by providing more solid links between IDLAMS and GIS industry and network investments established and used at the user site (e.g. ESRI products such as ArcInfo and ArcView).

BENEFIT: This project's scientific approach and resulting IDLAMS system will enable resource managers to quantify the effects of land management actions, both spatially and over time. Such an approach will reduce costs, enhance land use management responsiveness and effectiveness, disencumber military operations, enhance environmental compliance, and reduce conflicts between competing land uses. The system should also be usable at Department of Energy and other federal facilities and for resource management on federal lands. In this way, dual-use technology will be developed with broad applicability to Federal agencies.

ACCOMPLISHMENTS: In FY 1998, researchers developed and answered key design issues related to alternative land-use decision support architectures.

TRANSITION: Research results transferred to Army's Land Management Systems (LMS) decision support initiative for evaluation as an alternative architecture to support LMS goals. By using a case study to test and evaluate an object-oriented architecture approach to model integration and interoperability, the potential is established for providing LMS with many lessons learned.

PROJECT SUMMARY

PROJECT TITLE & ID: Threatened, Endangered, and Sensitive Resources; CS-507

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Army

LAB: Construction Engineering Research Laboratories - Champaign, IL

PRINCIPAL INVESTIGATOR: Dr. David Tazik

FY 1999 FUNDS: $150K

OBJECTIVE: Growing numbers of threatened, endangered, and sensitive species (TES) found on military lands increasingly result in mission constraints and impediments to land acquisition, potentially leading to reduced defense readiness; lengthy and costly litigation; and criminal and civil penalties. Major objectives of this research are to continue efforts to manage TES habitats and to mitigate the effects of military-unique impacts. Specific technical objectives are to: (1) develop regional guidelines for TES habitat/community evaluation and management; (2) evaluate approaches, methodologies, and techniques to enhance conservation of TES plant population; and (3) develop conceptual models of impacts of smokes, obscurants, and Chemical Stimulants on TES and make predictive assessments of effects of selected material and species.

BENEFIT: These efforts contribute substantively to a comprehensive, systematic, and integrated approach to TES management on military lands. Through this effort, the military will develop and demonstrate scientific and technical leadership in the management of TES. We will thus be better able to integrate TES considerations with military activities while avoiding mission impacts. On-going interagency coordination will yield benefits at the national, regional, and local levels.

TECHNICAL APPROACH AND RISKS: Regional TES management strategies will be developed for the Southeast Region using a plant community framework. Characterization, status, and management requirements will be defined for each plant community type and associated species based on the literature and coordination with regional experts. Management strategies will be developed that apply collectively to species with similar habitat requirements/plant community associations. TES plant populations enhancement approaches also will be evaluated for use by installation managers. We will scope the issue, evaluate specific enhancement techniques, and demonstrate specific guidelines. Small-scale field and greenhouse studies will be carried out. Impacts of smokes, obscurants and chemical stimulants on plants and animals will be evaluated. Toxicity levels will be determined for selected species based on existing information and supplemented by laboratory studies as needed. Emphasis will be placed on species most likely to be affected. Up to two species will be selected for more detailed study based on this risk assessment. A conceptual model will be developed for evaluating such impacts.

ACCOMPLISHMENTS: In FY 1998, under the regional habitat strategies component, a series of ten faunal TES species profiles on DoD installations in the southeastern United States were completed for a project total of eighteen. These profiles contain detailed information on species status and distribution, occurrence on military installations, life history and ecology, species habitat requirements, inventory and monitoring needs, impacts and causes of decline, and recommendations for restoration and management. A prototype regional handbook for the southeastern region will be published in early 1999. This document will address sensitive plant communities and potential impacts and will describe practices beneficial to these communities and their associated TES that are compatible with the military mission. Toxicity tests of Red-cockaded Woodpecker surrogates were conducted to determine if there are more subtle, long-term effects of smoke and fog oil that could affect population status. Investigations in FY 98 focused on physiological development of birds, their reproductive state, and immunotoxic effects.

TRANSITION: Products of this research will support the Army's environmental and endangered species management strategies and aid in efficiently meeting Army TES policies and regulatory requirements. A SERDP TES web page on faunal species is available online (http:/www.wes.army.mil/el/tes) and has been highly successful with over 8,000 hits recorded. Additionally, an article on the preliminary results of this study was published in the U.S. Fish and Wildlife Service Endangered Species Bulletin (Vol. 22:18-19).

PROJECT SUMMARY

PROJECT TITLE & ID: Digital Terrain Modeling and Distributed Soil Erosion Simulation/ Measurement for Minimizing Environmental Impacts of Military Training; CS-752

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Army

LAB: Construction Engineering Research Laboratories - Champaign, IL

PRINCIPAL INVESTIGATOR: Dr. Steven Warren

FY 1998 COMPLETED PROJECT

OBJECTIVE: The objective of this project is to develop methods and tools for prediction of the spatial and temporal distribution of runoff, soil erosion, and sediment deposition within watersheds. Soil erosion and consequent siltation of waterways have long been major environmental concerns on military installations. Most existing approaches to erosion/deposition modeling rely on lumped-parameter semi-empirical relationships developed for agricultural fields. Such approaches are unable to provide consistent results for complex watershed-scale runoff and erosion processes on military lands. Another primary limiting factor has been the inability to accurately represent the terrain in a digital form necessary for high resolution watershed-scale erosion and sediment transport modeling. The development of new-generation technical tools to model distributed surface erosion and runoff in complex terrains is a necessity. Such tools will provide a basis for predicting the environmental impacts of military-related activities and for the optimization of land rehabilitation programs for installations.

BENEFIT: This project improved the capability to generate accurate digital elevation models and perform topographic analyses for various terrain related applications. It improved the capability to estimate erosion/deposition potential as an input for choosing the optimal land use management and rehabilitation programs. Modeling of erosion and deposition will assist land managers and trainers in optimizing training schedules, delineating training areas, and monitoring changes over time. The models will also assist in maximizing availability of military lands with minimal impact to natural resources, especially to soil and vegetation. The overall net result of this research will be improved land management practices and reduced land maintenance costs.

ACCOMPLISHMENTS: In FY 1998, the CASC2D hydrology model was integrated into Watershed Modeling System. The hydrologic consequences of selected erosion control structures have been incorporated into the Simulated Water Erosion (SIMWE) erosion/deposition model. The dynamic visualization system to support landscape process simulations has been completed. Several manuscripts for submission to professional journals are in preparation and at least one has been submitted to date. These terrain modeling and erosion/deposition risk assessment techniques were successfully demonstrated

on both military and non-military lands.

TRANSITION: CASC2D, an improved real-time and post-event analysis for rainfall-runoff processes, is an integral part of the U.S. Army Engineer Research and Development Center's Watershed Management System for civil works properties. The Unit Stream Power Erosion/Deposition (USPED) replaces a component of the Army Training and Testing Area Carrying Capacity model and will be incorporated into land manager decision support systems such as IDLAMS. CAS2D, USPED, and SIMWE will support short- and long-range planning in the Army's Land Rehabilitation and Maintenance decision support system. These models are also an integral part of the Army's Land Management Systems demo at Fort Hood, TX, and the Upper Mississippi. Non-Department of Defense users include the Environmental Protection Agency, the National Park Service, the Agricultural Research Service, and the Natural Resources Conservation Service.

PROJECT SUMMARY

PROJECT TITLE & ID: Ecological Modeling for Military Land Use Decision Support; CS-758

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: Department of Energy

LAB: Oak Ridge National Laboratory - Oak Ridge, TN

PRINCIPAL INVESTIGATOR: Dr. Virginia H. Dale

FY 1998 COMPLETED PROJECT

OBJECTIVE: The analyses for land use decisions require ecological models that include the spatial distribution of habitat characteristics, biological population parameters, disturbance characteristics, geophysical changes, and landscape ecology phenomena. This SERDP project developed an integrated approach that incorporates the ecological models, their input assumptions, assessment endpoints, and a user interface into a useful application for Department of Defense (DoD) land managers.

BENEFIT: This research provides a quantitative method for assessing plans to maintain and conserve natural resources required for DoD missions. Integrating ecological models into a spatial context for land management will result in a clearer prioritization of ecological information, improved decisions, and fewer specialized management programs in the future. In addition to its use for management of natural resources, the proposed research is directly applicable to: (1) planning for facility closures and realignment; (2) evaluating natural resource management plans; (3) supporting compliance of environmental laws such as the Endangered Species Act and the National Environmental Policy Act; and (4) developing integrated risk assessments that address cumulative effects.

ACCOMPLISHMENTS: In FY 1998, this project completed a suite of ecological models that together can perdict where natural resources occur under various land management strategies and identify features that are at risk under particular land-use scenarios. The "toolbox" includes habitat, landscape, population, and metapopulation models at landscape and regional scales. Fort McCoy has implemented a land-use matrix model for the endangered Karner Blue Butterfly to guide future monitoring efforts for the butterfly.

TRANSITION: Ecological models are available through the Oak Ridge National Laboratory web site and have been submitted to widely-read, peer-reviewed journals.

PROJECT SUMMARY

PROJECT TITLE & ID: Advanced Biotelemetry for Resource Management; CS-759

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Army

LAB: Edgewood Research, Development, and Engineering Center

PRINCIPAL INVESTIGATOR: Dr. William Seegar

FY 1998 COMPLETED PROJECT

OBJECTIVE: The technical objective of the FY 98 effort is to develop and evaluate the potential of harmonic radar to track regional and local movements of small threatened, endangered, and sensitive species (such as birds and butterflies) for risk assessment and ecosystem management.

BENEFIT: The primary benefits of this project will be cost savings for DoD resource managers, enhanced research and management capabilities, and new technologies for a variety of users. Cost savings to the military will accrue in several ways. First, application of new methods and techniques will allow more effective study of special status species. Second, application of these methods and techniques will require fewer personnel than in the past. Third, fewer persons in the field for shorter periods will reduce interference with military activities. The near real-time integration of this data collection capability with both Geographic Information Systems (GIS) natural resource information and military land use activities will provide managers with a unique ability to support readiness on installations while managing for conservation and biodiversity.

ACCOMPLISHMENTS: In FY 1998, researchers conducted an initial investigation of harmonic radar and various permutations of the straight theoretical concept. A simple harmonic radar configuration has already been demonstrated by other research groups to track bees, beetles, and butterflies over very limited distances (several hundred meters). The approach is scientifically sound and has been replicated by at least 2 research groups, one in Canada and one in Great Britain.

TRANSITION: The use of harmonic radar tracking provides DoD and other land managers with sophisticated refinement of field ornithology at a time when there is tremendous pressure on many small avian species for management and conservation. This innovative diode-based radar system fills a critical information gathering technology gap and can significantly assist in the conservation of a vast array of avian species presently in jeopardy. The tools developed to mitigate bird strike hazards for military aircraft at airports can also be used at commercial airports.

PROJECT SUMMARY

PROJECT TITLE & ID: Development and Demonstration of a Risk Assessment Framework for Natural Resources on Military Training and Testing Lands; CS-1054

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Army

LAB: Construction Engineering Research Laboratories - Champaign, IL

PRINCIPAL INVESTIGATORS: Dr. Keturah Reinbold/Ms. Winifred Hodge

FY 1999 FUNDS: $600K

OBJECTIVE: Downsizing has increased demand at remaining installations for airspace, water and land area for military testing and training. Long-term suitability of training and testing areas and compliance with environmental regulations must be maintained. The objective of this effort is to develop a structured, scientifically valid risk assessment framework that can be rapidly and inexpensively applied to assess risks of single, multiple, or cumulative impacts of military training and testing activities on natural resources. This framework will incorporate physical, chemical, and biological stressors (including noise) and their direct and indirect effects, short and long term, on natural resources. The feasibility of linking Incremental Cost Analysis with the risk assessment framework will be examined.

BENEFIT: This framework will support a risk-based context which will assist Department of Defense (DoD) to better conduct training and testing activities while complying with environmental regulations, maintaining training and testing realism, and maintaining stewardship of natural resources.

TECHNICAL APPROACH AND RISKS: An Inter-Service User Advisory Group with representatives from all Services and both the testing and training communities will be formed. This group will help define the focus of the project, provide advice on prioritization of issues, and make recommendations on how to carry out technology transfer, how to prioritize planned tasks in case of budget cuts, and what tasks justify additional funding. An Interagency Scientific Advisory Group will help ensure the utility of the framework and its scientific defensibility. The Scientific Advisory Group will include scientists who are familiar with the range of relevant research that has been or is being conducted.

An initial scoping workshop will be held with the Advisory Groups to establish focus and priorities. The project will proceed by an iterative process of (1) consultation with users and DoD experts concerning a set of assessment issues, (2) summarization and organization of the consultation results, (3) framework development, and (4) review and direction by the advisory group. The results of the SERDP military training and testing assessment framework development project currently being conducted by U.S. Army Construction Engineering Research Laboratory and collaborators will serve as the first iteration of steps 1 and 2. The first iteration of the four-step process will be used to develop the first level (conceptual)

framework. The later iterations will be devoted to development of a second level (implementation) framework component for each of a series of generic types of stressors associated with training and testing. Examples could include soil and vegetation disturbance by vehicles, use of smokes and obscurants, overflights, fires, and spills of fuels. Each of these intermediate products will be designed so as to be usable by itself within the appropriate sphere of concern.

As each component is developed it will be linked into the overall framework so that effects can be combined into an overall assessment of risks to particular endpoints. The next set of iterations will be devoted to developing third level (operational) frameworks for specific training or testing activities at particular facilities. Finally, the complete framework and guidance for its implementation will be developed.

Technical risks include the scientific issues of environmental complexity and the methodological issues of designing a framework that is useful. The scientific issues are in a sense more manageable because the participants are experienced in the assessment of risks of diverse activities on complex sites and because the project is intended to identify gaps in knowledge and not to fill them all. In other words, the science of the risk assessment models and data will be state-of-the-art but will not exceed it. The methodological problems of developing a framework that is sufficiently simple in its implementation to be useful but sufficiently complex to incorporate all major issues is more difficult. In addition, the framework will need to be relevant to three services with facilities in a variety of environments and a variety of existing data, Geographic Information Systems, environmental models, etc. This problem will be addressed by using a hierarchical approach to organizing the framework, maintaining flexibility to substitute equivalent assessment tools, and regularly consulting with potential users.

ACCOMPLISHMENTS: In FY 1998, a conceptual framework was developed and reviewed by the User Advisory Group. Three top-priority military activities were identified by the User Advisory Group for activity-specific frameworks. They include: 1) aircraft overflights, 2) use of ocean ranges, and 3) firing at targets. Two papers were submitted for publication in the peer-reviewed journal *Human and Ecological Risk Assessment*.

TRANSITION: Specific DoD training or testing activities at particular facilities will be used to demonstrate risk assessment framework.

PROJECT SUMMARY

PROJECT TITLE & ID: Analysis and Assessment of Military and Non-Military Impacts on Biodiversity: Framework for Environmental Management on DoD Lands Using Mojave Desert as a Regional Case Study; CS-1055

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Army

LAB: Army Research Office

PRINCIPAL INVESTIGATOR: Dr. David Mouat

FY 1999 FUNDS: $550K

OBJECTIVE: The primary objective of this research is to provide Department of Defense (DoD) with techniques, tools, and training to carry out its military mission in the context of regional management of biodiversity and related ecological, stakeholder, cultural, and environmental resource concerns. The project develops and expands research and technology developed at Marine Corps Base (MCB) Camp Pendleton to address environmental problems at the regional scale in the western Mojave Desert (and will be coordinated with adjacent Department of Energy land holdings). It is analyzing the impacts of military and non-military stressors on patterns of biodiversity and related environmental resources and is assessing the impacts future land uses are likely to have on patterns of biodiversity. A strategic goal of the project is to enable the entire set of western Mojave installations to manage their resources unilaterally within the context of the region as a single entity. The ultimate deliverable will be transferred to the installations.

BENEFIT: A principal benefit of the project will be a capability of the military to evaluate impacts of both DoD and non-DoD stressors (such as off-road vehicle use and suburban development) on military issues. Through integrated regional ecosystem management, the military will far more effectively be able to negotiate biodiversity and other ecosystem management issues with surrounding stakeholders, ensuring minimal environmental damage while maintaining and enhancing the military mission.

TECHNICAL APPROACH AND RISKS: This project employs an integrated technical approach consisting of four components or phases. The development phase consists of the development of a Quality Assurance/Quality Control plan and a peer-reviewed experimental design, the initiation of a spatially-oriented data base management and decision support system, the organization of a military and non-military stakeholder group to identify environmental issues and human valuations of the regional ecosystem both within and outside the military context, and identification of military and non-military stressors. The basic methodology for deriving habitat information through vegetation - terrain correlation is being established. The data assembly phase consists of continued work in deriving vegetation information for habitat characterization, the development of comprehensive data bases for biotic and abiotic resources, and the determination of key species (including the Desert Tortoise) along with their habitat

requirements.

Much of this work involves interaction with ongoing Legacy Program activities (for their data bases) through the U.S. Geological Survey's National Biological Resources Division and other groups. The analysis and assessments phase consists of determining habitat relationships and assessing management strategies for the Desert Tortoise and other key species, assessing the "sweep" potential for using certain key species to derive habitat and management strategies for other species, and evaluating the effects of existing land uses and other stressors on habitat and biodiversity. The modeling and products delivery phase involves modeling the effects of future land use scenarios on stressors and on the likely impacts on biodiversity and related environmental resources. It also involves reporting and publication coordination, stakeholder briefings, and technology transfer activities. A number of technical risks are associated with the proposed activities. Some involve the need for qualified individuals at the installations to implement the products produced. Possible incompatibility of disparate databases is another potential risk.

ACCOMPLISHMENTS: During the second year of this SERDP project, a comprehensive, peer-reviewed research plan was completed and accepted. The Mojave Desert Ecosystem was defined and hexagonal coverage of the Mojave Desert will be based on EPA's Environmental Monitoring and Assessment Program (EMAP) hexagonal grid. Field data gathered for terrestrial vertebrate and landscape information at Joshua Tree National Park and The U.S. Marine Corp, 29 Palms. Mojave biodiversity infrastructure was identified and an assessment of species richness was completed.

TRANSITION: Results of this project will further provide the military with techniques, tools, and training to evaluate the impacts of future development and land uses on the environment and to be able to coordinate responses. Technology transfer activities will be initiated to implement the framework developed for MCB Camp Pendleton at MCAGCC 29 Palms.

PROJECT SUMMARY

PROJECT TITLE & ID: Marine Mammal Responses to Low Frequency Sound; CS-1069

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Navy

LAB: Office of Naval Research - Arlington, VA

PRINCIPAL INVESTIGATOR: Dr. Robert C. Gisiner

FY 1998 COMPLETED PROJECT

OBJECTIVE: Develop monitoring and mitigation capabilities for assessing the impacts of manmade low frequency sound on the marine environment, with emphasis on marine mammals. Marine mammals are protected as a group by special legislation, the Marine Mammal Protection Act (MMPA). Many marine mammals are also listed under the Endangered Species Act because their numbers have been severely reduced by hunting and habitat destruction. We currently do not have an adequate understanding of the effects of manmade sound on the environment, but large whales, which emit low frequency sound for sensing and communication, and other marine mammals that dive into the deep sound conducting channel, may be vulnerable to exposure to manmade, low frequency sound sources. This program aims to collect data to determine if Navy activities affect marine mammals while exploring new technology that will better enable us to monitor the marine environment.

BENEFIT: One benefit is the acquisition of data on the effects of manmade low frequency sound on marine mammals. There is relatively little data on this subject and therefore little in the way of regulatory guidelines or standardized assessment and mitigation procedures. The second benefit is the development of technology to improve detection and monitoring of marine mammals. These developments are of critical interest to the Navy, and are also applicable to a variety of commercial and recreational activities that emit sound and, therefore, might have an impact on marine mammals.

ACCOMPLISHMENTS: Cornell University conducted research to quantify the responses of humpback whales to experimental levels and the operational level of an Acoustic Thermometry of Ocean Climate (ATOC) oceanographic signal. Results indicate no immediate obvious response by individual whales during exposures to received levels as high as 130 dB. There was no noticeable change in the number and density of animals or the number of singers or the behaviors of animals relative to the LFS acoustic condition (sound on versus off) over a period of several months. There was only one consistent statistically significant response: the distance between successive surfacings for a whale increased with increasing received level. However, this effect explains less than two percent of the total variation in this measure and the response is not considered biologically significant.

TRANSITION: The results of this project will be widely disseminated to the scientific and DoD user community and should play a key role in the formulation of future DoD/Navy policy on this issue.

PROJECT SUMMARY

PROJECT TITLE & ID: Information Technology Tools for Assessment and Prediction of the Potential Effects of Military Noise on Marine Mammals; CS-1082

RESEARCH CATEGORY: 6.1 Basic Research

LEAD AGENCY: U.S. Navy

LAB: SPAWARSYSCEN - San Diego, CA

PRINCIPAL INVESTIGATOR: Dr. David Helweg

FY 1999 FUNDS: $370K

OBJECTIVE: Currently, the Department of Defense (DoD) lacks scientifically defensible tools for the safe operation of many of their training and testing systems [e.g., Low Frequency Active (LFA) sonar and Shipshock] in the presence of marine mammals. Although there is increasing concern over the effects on marine mammals of man made sound in the oceans, there is very little direct information about which sound frequency-intensity combinations damage marine mammal hearing. Our broad objective is to transition information about the effects of DoD sound types on marine mammal auditory anatomy to predictive models and mitigation tools. This effort responds directly to the DoD capability to comply with the National Environmental Policy Act requirements and will contribute directly to answering the National Research Council's Research Needs related to the effect of low-frequency sound on marine mammals.

BENEFIT: DoD lacks scientifically defensible positions concerning the safe use of LFA and Shipshock testing in the presence of marine mammals. These research tasks will provide information that feed directly into the assessment and prediction of military noise effects on marine mammals.

TECHNICAL APPROACH AND RISKS: This project consists of three inter-related tasks. Task 1 consists of otopathological analyses of marine mammal ears. Task 2 consists of otopathological analyses of baleen whale ears, the results of which will motivate development of a biomimetic model of baleen whale auditory responsiveness to DoD sound types. Task 3 will utilize predictions about sensitivity generated in Task 2, and statistical sampling models and acoustical classification algorithms, to automate the U.S. Navy's Integrated Undersea Surveillance System (IUSS) for mapping the distribution of whales in the Southern California region. Task 3 is coordinated with other related SERDP efforts on the potential effect of anthropogenic sound on marine mammals.

ACCOMPLISHMENTS: For task 2, initial data were gathered from one humpback whale ear and used to generate a predicted whale audiogram. For task 3, a cost/benefit analysis of the application of decommissioned SOSUS assets to whale bioacoustical research also was initiated.

TRANSITION: The results will provide information that will feed directly into the assessment and prediction of military noise effects on marine mammals.

PROJECT SUMMARY

PROJECT TITLE & ID: Assessment of Training Noise Impacts on the Red-Cockaded Woodpecker; CS-1083

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Army

LAB: Construction Engineering Research Laboratories - Champaign, IL

PRINCIPAL INVESTIGATOR: Dr. Larry Pater

FY 1999 FUNDS: $450K

OBJECTIVE: The objective of this project is to determine the impact of certain types of training noise on the endangered red-cockaded woodpecker (RCW). The project also will develop and make available cost-effective techniques that installations and other researchers can use to evaluate and monitor effects of military noise on animal species. These techniques include the capability to characterize noise stimuli, document physiological and behavioral responses, and determine resulting population effects due to military noise. The proposed research will provide information required to assess and manage risk to both military training capability and the endangered RCW and will provide a factual basis for mitigation and management protocols and guidelines.

BENEFIT: This project will provide the data required to address RCW regulatory issues, to guide effective impact management on Threatened and Endangered Species (TES) populations, and to preserve TES populations. This will help to alleviate impacts on training capability, avoid the need to acquire additional training land, and minimize litigation and delays.

TECHNICAL APPROACH AND RISKS: The approach assumes that proximate effects can be linked to individual fitness, which in turn can be linked to population effects. The proximate response measures that will be used are flush from nest cavity, feeding of young in nest, and feeding behavior (non-nesting). Field studies of the in-situ response of the animal to the measured noise events will be used to determine dose-response relationships. Individual fitness measures will include: number of young fledged per nest, adult turnover, group size, and mating success. These demographic parameters will be correlated with measured noise levels. A second strategy to assess noise effects on individual fitness will correlate historic demographic data with estimated noise levels, using available training noise models. The empirical data from these efforts will be integrated into leveraged RCW population models to assess noise impacts at the population level. Four noise types will be considered: artillery noise, small arms noise, helicopter noise, and maneuver noise. The latter is a mix of the other three types.

ACCOMPLISHMENTS: In the first year of this project, field data were collected at Ft. Stewart, GA and laboratory development of an audiogram for the RCW was completed.

TRANSITION: Research results will transition as Army land management decision support tools.

PROJECT SUMMARY

PROJECT TITLE & ID: Error and Uncertainty Analysis for Ecological Modeling and Simulation; CS-1096

RESEARCH CATEGORY: 6.1 Basic Research

LEAD AGENCY: U.S. Army

LAB: Construction Engineering Research Laboratories - Champaign, IL

PRINCIPAL INVESTIGATOR: Dr. George Gertner - University of Illinois

FY 1999 FUNDS: $300K

OBJECTIVE: With the growing importance of simulation modeling in natural and cultural resource assessment and management, the Department of Defense (DoD) recognizes the need for a comprehensive framework to analyze uncertainty of simulation results. Most data employed in simulation modeling are estimates of the true parameters and, therefore, have an associated uncertainty. Error budgets can be used to assess the quality of the overall simulation system. Although progress has been made in the areas of uncertainty analysis and error budgets, there is a need to develop the statistical and computational tools. These tools will enable model users to jointly assess and quantify the sources and magnitude of errors associated with large-scale DoD simulation models used for resource assessment and management.

BENEFIT: This project will provide the rationale to account for the effect of different sources of error on the uncertainty of model predictions, and also provide the rationale for efficiently reducing the uncertainty. This methodology will be relevant to all users of ecological and environmental models.

TECHNICAL APPROACH AND RISKS: The overall goal is to account for the sources and the effect of uncertainty in simulation modeling. The proposed analytical framework will be made available as a user-friendly interactive software package with the means to assess and exert control over the quality of the simulation results. In parallel, the project will apply this methodology to a monitoring-modeling system employed by the military for assessment and/or management of natural and cultural resources at one military installation.

ACCOMPLISHMENTS: In FY 1998, three land simulation models were selected for the case study at Fort Hood, TX: 1) the Army's Training and Testing Area Carrying Capacity model, 2) the Terrain Modeling and Soil Erosion, and 3) a plant simulation model. The latter two models are being used to enhance the first simulation model. The formal framework for error analysis of large spatially-explicit simulation models was initiated and approximately 100 different sources of error identified.

TRANSITION: This capability will provide the necessary quality control/assurance mechanisms to support DoD decision support systems regarding natural and cultural resources.

PROJECT SUMMARY

PROJECT TITLE & ID: Ecological Modeling and Simulation Using Error and Uncertainty Analysis; CS-1097

RESEARCH CATEGORY: 6.1 Basic Research

LEAD AGENCY: Department of Energy

LAB: Oak Ridge National Laboratory - Oak Ridge, TN

PRINCIPAL INVESTIGATOR: Dr. Anthony King

FY 1999 FUNDS: $256K

OBJECTIVE: Ecological models are increasingly becoming spatially-explicit, often used in conjunction with a geographical information system (GIS). This project will: 1) identify and evaluate methods for quantifying uncertainty in spatial data for ecological models; 2) incorporate Monte Carlo analysis into a framework for uncertainty and error analysis of spatial data in ecological models; 3) test and demonstrate the Monte Carlo framework and tools with a case study.

BENEFIT: Provide the rationale to account for the effect of different sources of error on the uncertainty of predictions made through ecological models, and also provide the rationale for efficiently reducing the uncertainty. These methods and tools will be relevant to all users of ecological and environmental models.

TECHNICAL APPROACH AND RISKS: The overall goal is to account for the sources and the effect of uncertainty in simulation modeling. The investigation will complement the error budget approach and will be closely coordinated with SERDP project CS-1096 to ensure no duplication of effort. The Monte Carlo framework will be implemented as general and modular software designed to maximize the ease with which alternative ecological modes can be incorporated into the analytical framework. This approach will facilitate application of the analytical methodology to different installations, ecological models, and applications, and will be compatible with specifications and requirements of CS-1096.

ACCOMPLISHMENTS: In FY 1998, a preliminary literature survey of existing methods dealing with error and uncertainty in spatial data was completed. Stochastic simulation was identified as the most broadly applicable approach. Categorical spatial data were selected and sequential indicator simulation was identified as the most appropriate method of stochastic simulation for categorical data in ecological models. Two case studies were chosen, the black-capped vireo and golden-cheeked warbler populations at Fort Hood, TX, using habitat and population models developed at Fort Knox.

TRANSITION: Incorporation of these methods and tools into the land-use decision process as part of an overall error budget analysis, and as part of land-management decision support systems such as the Integrated Dynamic Landscape Analysis and Modeling System (IDLAMS) and Land Management System (LMS) will directly benefit DoD conservation practices.

PROJECT SUMMARY

PROJECT TITLE & ID: Emerging and Contemporary Technologies in Remote Sensing for Ecosystem Assessment and Change Detection on Military Reservations; CS-1098

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. ARMY

LAB: Topographic Engineering Center - Fort Belvoir, VA

PRINCIPAL INVESTIGATOR: Mr. Randall Karalus

FY 1999 FUNDS: $1,050K

OBJECTIVE: This project will be conducted in coordination with the University of Nevada at Reno and Utah State University. The objectives of this project are to: stratify the landscapes of individual military ranges using contemporary and emerging remote sensing technologies; identify the fundamental vegetation and soil attributes of military ranges as they relate to plant succession; establish ecosystem response and recovery in relation to disturbance (land use) through retrospective studies with spatially-explicit spectral-based indices; identify the spatial, spectral, and temporal attributes of remote sensing systems necessary to identify ecotones and to distinguish along environmental and disturbance gradients; and lastly, develop methods for scaling indices between coarse and fine resolution imagery.

BENEFIT: The project will provide DoD managers with efficient models and techniques to better characterize and quantify the carrying capacity of land resources to support military training and testing. Managers will be able to predict the impacts of land-based usage, understand the risk associated with use, and analyze decisions to provide training flexibility versus environmental or ecological damage. This includes: models for change detection of land use; methods for scale transitions; relationships between hierarchical scheme of spectral and spatial resolution to ecotone/biological thresholds/degradation; and a better understanding of ecosystem response and recovery in relation to disturbance (land use). Results also will include refined ecosystem maps and new field and image data.

TECHNICAL APPROACH AND RISKS: The technical approach for this project is essentially a composite of: (1) mapping the installation; (2) correlating the fundamental attributes of disturbance and plant succession; (3) analyzing, retrospectively, the ecological history of each installation in relation to land use, and; (4) assessing high resolution systems to identify the sensor attributes necessary to monitor changes in plant species composition along disturbance gradients and plant succession stages.

Mapping of installations or select components thereof will provide maps that identify areas of change or disturbance that need further investigation. Mapping units will be created based upon botanical composition and related land cover characteristics. The mapping and stratification campaign will occur during peak wet and dry seasons. Contemporary satellite imagery will identify and map landscape level

communities associations. The mapping units will represent community types defined by carrying capacity models, such as LCTA and LBCC, and classification systems used by other federal agencies. Five hierarchical levels of classification are to be tested: 1) serial stages within a plant community; 2) plant communities along an environmental gradient; 3) dominant species along an environmental gradient; 4) dominant species; and 5) dominant life form. During FY99, vegetation maps will be completed for Camp Williams, UT, and Ft. Bliss, TX and initiate algorithm development for improved and more efficient image processing. The project leverages with a significant number of other programs and research efforts.

ACCOMPLISHMENTS: In FY 1998, a retrospective study was initiated for Camp Williams, UT, and Ft. Bliss, TX. An algorithm was developed for processing remotely sensed data (Landsat MSS and TM imagery). Aerial imagery was collected at Ft. Bliss in June and August and at Camp Williams in July. Researchers also have initiated the vegetation mapping and ecotone analysis efforts.

TRANSITION: DoD demonstration sites for transitioning this technology have been chosen.

PROJECT SUMMARY

PROJECT TITLE & ID: Predicting the Effects of Ecosystem Fragmentation and Restoration: Management Models for Animal Populations; CS-1100

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Army

LAB: Construction Engineering Research Laboratories - Champaign, IL

PRINCIPAL INVESTIGATOR: Dr. Thomas Sisk - Northern Arizona University

FY 1999 FUNDS: $170K

OBJECTIVE: An improved understanding of the effects of ecosystem fragmentation is required for better integration of DoD land management and training objectives and for maximizing the benefits associated with land rehabilitation and habitat restoration. The development of practical tools to predict the effects of habitat fragmentation and design appropriate mitigation efforts has progressed slowly. DoD training and related activities on and adjacent to military lands often contribute to fragmentation and affect species of special concern, including threatened and endangered species. This project proposes to develop species-specific models that predict the responses of mobile animal species in heterogeneous landscapes. Modeling efforts will build on connections between life history characteristics and the responses of mobile animals to habitat fragmentation and restoration. Field research will permit parameterization of models and testing of model predictions, leading to refinement of the conceptual approach. The primary foci are the ponderosa pine forests and riparian habitats on military lands. These two habitat types are widespread throughout the U.S. and currently the subject of great management debate.

BENEFIT: The project will link field and remotely sensed data in validated landscape models that will permit comparison of alternative land use strategies on wildlife species of management concern. Extensive field testing of model predictions in different environments will permit evaluations of model effectiveness in forecasting the responses of a wide range of species to landscape-scale alterations in forested and riparian habitats. The model will operate in the ARC and ArcView geographic information system environments. Through manipulation of habitat maps, the Effective Area Model (EAM) will be capable of predicting the effects of alternative landscape modifications -- habitat fragmentation due to operational activities, or habitat restoration resulting from rehabilitation or mitigation efforts -- on a wide range of animal species.

TECHNICAL APPROACH AND RISKS: The project is a cooperative effort involving Northern Arizona University, Colorado State University, the Ponderosa Pine Ecosystem Restoration Project, the Semi-Arid Land Surface Atmosphere (SALSA) Project, Camp Navajo (U.S. Army and Arizona Army National Guard), and Ft. Huachuca (U.S. Army). The project links three areas of investigation: 1) acquisition of ecological field data on the responses of animals to habitat fragmentation; 2) the mapping of animal habitats in three dimensions and at scales relevant to habitat management; and 3) the linking of empirical ecological data and spatially explicit habitat information in a management-oriented model, the

EAM.

Field data will be collected along transects running orthogonal to habitat edges and will quantify population density and other relevant parameters at different distances from habitat edges. Statistical and mathematical approaches will permit characterization of species' responses. Field research will target species of special interest to managers, such as sensitive, threatened and endangered species, but it also will include a broad range of species that might influence the populations species of management concern through, for example, competition or predation.

Habitat mapping will rely on remotely-sensed data and field measurements. LANDSAT imagery and aerial photography will permit delineation of the spatial extent, shape, and juxtaposition of habitat patches. Important structural attributes will be explored through the use of Synthetic Aperture Radar, aerial photography, and field measurements. Overlay of pertinent data sets in a Geographical Information System environment will allow integration of habitat attributes and identification of floristically and structurally distinct habitat types, as well as the edges that separate different habitat patches. Completed habitat maps will serve as input to the EAM.

The modeling approach will project species-specific edge responses, measured in the field and characterized mathematically, onto the spatially explicit habitat maps, weighting each habitat patch according to its area and the influence of the surrounding habitat on species abundance and demographic variables.

ACCOMPLISHMENTS: In FY 1998, researchers solidified their collaboration with the SALSA Program, facilitating sharing of remotely-sensed data, leveraging of field efforts, and cooperation on logistics. Sites were selected and field research was completed at the Camp Navajo and Mt. Trumbull Ponderosa Pine sites. Avian census efforts at Ponderosa Pine study sites were completed. Raw, high-resolution TMS data were acquired for the Ft. Huachuca/San Pedro study sites and field efforts were initiated at the Ft. Huachuca/San Pedro study site.

TRANSITION: The project results will be provided to land managers who will link field and remotely sensed data in validated landscape models that will permit comparison of alternative land use strategies on wildlife species of management concern.

PROJECT SUMMARY

PROJECT TITLE & ID: Improved Units of Measure for Training and Testing Area Carrying Capacity Estimation; CS-1102

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Army

LAB: Construction Engineering Research Laboratories - Champaign, IL

PRINCIPAL INVESTIGATOR: Mr. Alan Anderson

FY 1999 FUNDS: $550K

OBJECTIVE: DoD training and testing land carrying capacity is the ability of specific land parcels to accommodate military training exercises and mission activity. In 1995, the Army funded a proof-of-concept study to develop a methodology for estimating the operation and support costs of using land for training ground forces. The methodology known as Army Training and Testing Area Carrying Capacity (ATTACC) consisted of three components: training, environment, and economic. This project proposes to significantly improve the methodology as an installation management tool to better predict the environmental consequences of military training activities. The focus of this project is to develop quantitative units of measure (such as erosion and species composition on land) to estimate training and testing land carrying capacity, extend the spatial and temporal scale of the methodology to include individual training areas and changes in training and land condition throughout the year, and validate the improved methodology.

BENEFIT: By providing an improved methodology, mission impacts can more accurately be matched to the ecological capability of military lands to support those activities resulting in decreased land maintenance costs, maintaining realistic training conditions, and increasing land use capacities.

TECHNICAL APPROACH AND RISKS: In the existing ATTACC methodology, erosion status is estimated using the Revised Universal Soil Loss Equation (RUSLE). The RUSLE equation was developed for agricultural lands and does not account for complex topography that is typical of military lands. The unit stream power approach for estimating the topographic factor of RUSLE will be used to account for complex topography typical of military lands. This project will extend the current ATTACC methodology to include wind erosion in addition to water erosion. Existing wind erosion models will be evaluated to determine which is the most applicable to military lands based on data requirements and model assumptions. The results from the existing SERDP project on Terrain Modeling and Soil Erosion are being used to improve estimates of land condition and can be extended to off-site impacts (sedimentation and water quality). It also will extend the ATTACC methodology to include plant species composition as a measure of land condition. To incorporate species composition into the ATTACC model, the Ecological Dynamics Simulation (EDYS) model will be utilized.

The EDYS model is a process-based model that predicts changes in species composition that naturally occur over time and in response to natural disturbances. A military impacts sub-model will be developed for the EDYS model. The military impacts sub-model will translate training/testing activities into changes in soil and vegetation processes. Existing DoD impact studies will be used to estimate the primary impacts of military activities on soil and vegetation processes. The ATTACC methodology also will be extended to account for climatic variation throughout a year. Components of the ATTACC model will be modified to incorporate time varying climatic factors. Temporal differences in mission impacts on the vegetative cover factor will be estimated from existing DoD impact studies.

ACCOMPLISHMENTS: IN FY 1998 researchers commenced the sensitivity analysis to provide a basis for ATTACC model improvements. The military impacts submodel for Ecological Dynamics Simulation (EDYS) was revised to allow changes in species composition associated with military activities. A wind erosion model was selected for incorporation into ATTACC and the model evaluation process is underway. Training impact factors are being developed to account for seasonal variations.

TRANSITION: This project will feed into the current ATTACC methodology to include wind erosion, land condition, and plant species composition.

PROJECT SUMMARY

PROJECT TITLE & ID: Identify Resilient Plant Characteristics and Develop a Wear Resistant Plant Cultivar for Use on Military Training Lands; CS-1103

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Army

LAB: U.S. Army Cold Regions Research and Engineering Laboratory - Hanover, NH

PRINCIPAL INVESTIGATOR: Mr. Antonio Palazzo

FY 1999 FUNDS: $350K

OBJECTIVE: Wear-resistant plants are needed to mitigate environmental impacts and improve the use of DoD training lands. Knowledge of the relationships between military training and plant injury, regrowth, and wear resistance is limited. Plant and soil data will be combined allowing land users to make knowledgeable choices concerning plant selection and site-rehabilitation procedures to reduce soil erosion. Resilient plants have been previously identified at several DoD/Army training sites using field surveys. Several resilient plant clones have also been collected from Yakima Training Center, Fort Carson, and Logan, UT. This project intends to use these collections and other plants to breed new more resilient cultivars. A second objective is to conduct field and greenhouse studies to quantify the degree of compaction that occurs during training and relate soil condition to root injury in plants with known resilience. This effort leverages existing DoD Tri-Service Environmental Quality Research and Development on plant selection and plant characteristics to attain an optimal use of land capacity to sustain military training and testing.

BENEFIT: This project will provide DoD guidance for mitigation methods and will provide more resilient plant species that will help to increase training opportunities on existing training areas. This guidance will assist land managers and trainers in making choices on training schedules and in estimating cost and time requirements for maintaining military readiness.

TECHNICAL APPROACH AND RISKS: The activities of the proposed research are to identify and develop training-resilient plant cultivars and conduct field and greenhouse studies to quantify the degree of soil compaction that occurs during training, relating this soil condition to root injury in plants with known resilience.

ACCOMPLISHMENTS: Based on the results of evaluation trials, the plant breeding component narrowed candidate species to eight for Yakima Training Center, WA and six for Fort Carson, CO. Based on evaluation data at YTC, three wheatgrass accessions were established in a space-planted breeding nursery. Researchers published in FY 1998 three refereed manuscripts, one conference paper, and an abstract describing plant-breeding results. For the soil compaction component, Yakima Training Center, Fort Carson and Fort Drum preliminary cone penetrometer results indicate finer textured soils and those

Fort Carson and Fort Drum preliminary cone penetrometer results indicate finer textured soils and those with higher moisture content had greater compaction and initiated a greenhouse study to develop data sets on root growth in compacted soils.

TRANSITION: The results of this SERDP project will be integrated into land management decision support tools to provide DoD land managers the necessary guidance for mitigation methods and more resilient plant species that will help to increase training opportunities on existing training areas.

PROJECT SUMMARY

PROJECT TITLE & ID: SERDP Ecosystem Management Project; CS-1114

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Army

LAB: Engineer Research and Development Center

PRINCIPAL INVESTIGATOR: Mr. William Goran

FY 1999 FUNDS: $2,440K

OBJECTIVE: The objective of this project is to plan, coordinate and manage a SERDP Ecosystem Management Project (SEMP) initiative that focuses on ecosystem science relevant to DoD ecosystem management concerns. This includes establishing and managing one (or more) long-term ecosystem monitoring sites on DoD facilities, and conducting multiple ecosystem research efforts at these and/or additional facilities.

BENEFIT: With DUSD(ES) guidance that management of DoD lands be accomplished using an ecosystem approach, the Services' Conservation user communities are beginning to plan in that direction. However, as the SERDP Management-Scale Ecosystem Research Workshop (June, 1997) noted there is a critical need for scientific information to support this approach, especially as it relates to integrating ecosystem management with mission concerns. The success of user plans will depend on the capabilities and increased knowledge generated by research investment. SEMP will facilitate a number of studies that can be sufficiently planned and funded to allow a full array of remote sensing, ground truth experiments, modeling, cause-effect studies, etc. to be integrated to address complex problems. This contributes to data sharing, leveraging, and joint publications, supported by major experimental findings. Focused development of an ecosystem research plan, appropriate instrumentation and monitoring to support this research, and identification and selection of the most effective, technically sound research efforts to answer user needs will all contribute to the science and understanding necessary for an ecosystem approach to land management.

TECHNICAL APPROACH AND RISKS: FY99 tasks include: (1) establishing roles, responsibilities and procedures for multi-year research and development activities to be conducted at the initial SEMP host site, (2) contract management and oversight of the FY99 research submitted toward the first SEMP Statement of Need (SON) and management and oversight for FY00 SON development and solicitation, (3) management of and support for the Technical Advisory Committee (TAC) established for SEMP, (4) gathering and analysis of monitoring and background data for this host site and the surrounding region into a status report and monitoring plan, (5) design and develop a data repository, (6) acquisition and fielding of additional equipment/stations/ protocols for data collection, and (7) development and implementation of a SEMP website. In addition, specific research efforts will be conducted at the host site, and new

research efforts will be solicited through normal SERDP SON processes.

The U.S. Army Engineer Research and Development Center (USAERDC) has the primary responsibility for management of SEMP, development and execution of overall research and monitoring plans, interface with host research sites, and oversight of specific research projects. The SEMP Working Group, formed in FY98, to be involved with this effort during the first half of FY99, advising USAERDC on SEMP activities and plans, helping to draft a concept paper on ecosystem management. USAERDC (with assistance from other performers) will collaborate with Ft. Benning on the monitoring status reports and plan as well as acquisition of new data and equipment. The TAC will review ongoing project work and proposed research following peer evaluation.

Specific opportunities will be found to address DoD-wide priorities within the ecological parameters of the selected sites. Long-term monitoring of appropriate ecosystem indicators will be a central component of the SEMP, and will be linked to the overall research and development plan from the beginning.

ACCOMPLISHMENTS: In FY 1998, the SEMP working group assisted USAERDC in the development of an overall plan for SEMP. This plan calls for one initial SEMP host site, and a sequence of research activities focused on change indicators, then disturbance thresholds, then finally adaptive management options. The plan also calls for a sequence of steps leading to a fully instrumented long-term monitoring site. USAERDC and the SEMP Working Group developed a set of criteria for the initial SEMP host site, picking first the southeastern region. Fort Benning, Georgia was selected as the host site and a Memorandum of Understanding (MOU) between USAERDC and Fort Benning was prepared.

The SEMP Working Group issued the first research proposal call for "Determination of Indicators of Ecological Change." The proposals were peer reviewed and a subset of three were selected for funding: 1) “Determination of Indicators of Ecological Change”; 2) “Indicators of Ecological Change”; and 3) “Development of Ecological Indicator Guilds for Land Management.”

The SEMP TAC was established to provide technical review and oversight of SEMP activities and plans, linkages to related research activities and findings, continuity across the diverse research efforts, and assistance in transferring of SEMP findings and outcomes to the scientific and Defense Land Management Communities.

TRANSITION: Project results will be integrated into DoD ecosystem management policy and procedures to provide DoD land managers the necessary guidance and tools for a sustaining future military training and testing. The monitoring and research results will also be available to other Federal land managers.

PROJECT SUMMARY

PROJECT TITLE & ID: Diagnostic Tools and Reclamation Technology for Mitigation Impacts of DoD/DOE Activities on Arid Areas; CS-1131

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: Department of Energy

LAB: DOE-Las Vegas/Bechtel Nevada

PRINCIPAL INVESTIGATOR: Dr. W. Kent Ostler

FY 1999 FUNDS: $545K

OBJECTIVE: This project is designed to overcome current gaps in diagnostic capabilities needed to distinguish between various degrees of sustainable and non-sustainable impacts due to military training and testing or earth-disturbing activities in desert ecosystems. The project also will develop and evaluate new and cost-effective techniques for rehabilitation and restoration of such disturbed habitats. These diagnostic tools will enable management to maximize utilization of limited training environs and thus increase operational readiness.

BENEFIT: Approximately 70% of all U.S. military training lands are located in arid areas that will benefit directly from these technologies. Under current technology, it is estimated that up to 35% of revegetation projects will fail. Applying the results of this project will increase the success of the restoration and possibly save DoD as much as 5 million dollars annually.

Technologies developed by this program can be used for a variety of applications currently needed by government agencies with land management responsibilities in both arid and moist environments. The primary applications include: 1) evaluating and monitoring the site's ability to recover from various levels of impacts. 2) rapidly assessing shrub density, height, diameter, size class and percent canopy cover (important for controlling erosion), and 3) developing cost-effective revegetation techniques.

TECHNICAL APPROACH AND RISKS: The technologies being evaluated and tested are divided into two principal areas: diagnostics and restoration techniques. The diagnostic techniques are further divided into image collection and image processing techniques.

Image Collection Techniques - New rapid detection methods will be developed using hand-held digital cameras and Hi-8 camcorders to record selected ground data such as panoramic views with vertical and horizontal scale references to record shrub height and canopy width, regularly-spaced closeups to document shrub sprouts, percentage of shrubs alive, emergence of seedlings, and morphological demographic data (approximate proportion of shrubs at different ages or sizes). This technique can utilize permanent transects or photo points to assess year to year trends and to be compatible with current

to DVD CDS for archiving. Individual images will be analyzed independently using several commercially available software packages that have digital-capture capabilities to quantify selected spectral bands, such as those wavelengths that correspond to living tissues.

Image Processing Techniques - Images shot from helicopter or fixed-wing aircraft along selected or permanently marked flight lines can also be evaluated using computer technologies to provide rapid assessment of vegetation such as total number of shrubs and cover present in selected areas. For example, using aerial photography of a scale from 1:2,000 to 1:24,000 it is possible to selectively scan a photograph and process the image data to rapidly calculate shrub density and total shrub cover in less than a minute per plot. Additionally, data are analyzed statistically to show size classes of shrubs, a parameter important for assessing impacts from training exercises and shrub demographics. Photographic images taken of Mojave Desert habitat at the Nevada Test Site (photo scales of: 1:2000, 1:4000, 1:8000, 1:16000, and 1:24000) which are comparable to habitat at Fort Irwin, will be used to determine the optimal photo scale and associated error functions. Software packages to be evaluated will include SigmaScan, SigmaScan Pro, and Delta T. Except for preliminary findings at the Nevada Test Site, no evidence has been found that this promising method has ever been used to count shrubs and estimate shrub cover collectively or by individual shrub classes. Use of this technique alone could significantly reduce site evaluation time by several orders of magnitude, while increasing data reliability and application to other desert ranges.

Restoration Techniques - The resiliency of a site to training exercises depends on the frequency and nature of the impacts as well as the potential for restoration. The potential for restoration is determined by such things as plant species present, seed bank, soil moisture, and nutrients. At some sites, a shift in plant community composition may also occur, with more sensitive species being replaced by plants more resistant to training impacts. Recovery may occur naturally and keep pace with the level of disturbance at some sites, depending on the nature and frequency of the disturbance, or it may require selected restoration techniques to recover from adverse training impacts before sustainable restoration is achieved.

All of the techniques for both the diagnostic and restoration areas have not been proven for these areas and contain some risk. For some techniques the risk is higher but we are generally testing multiple techniques to enhance our opportunity for success.

ACCOMPLISHMENTS: This is a FY 1999 New Start.

TRANSITION: These results will be integrated into land management decision support tools to provide DoD land managers the necessary guidance for mitigation methods that will help to increase training opportunities on existing training areas.

APPENDIX D
Pollution Prevention Project Summaries

PROJECT SUMMARY

PROJECT TITLE & ID: Organic Protective Coatings and Application Technology; PP-65

RESEARCH CATEGORY: 6.3 Advanced Development

LEAD AGENCY: U.S. Navy

LAB: Naval Air Warfare Center Aircraft Division - Patuxent River, MD

PRINCIPAL INVESTIGATOR: Dr. Kevin Kovaleski

FY 1998 COMPLETED PROJECT

OBJECTIVE: The objective is to develop high performance, non-toxic, low volatile organic compound (VOC) content coatings which provide protection against environmental degradation as well as passive countermeasures for Navy aircraft and weapon systems. The Navy currently uses numerous coatings due to their diverse functions, variety of substrate applications, and severe operational environment. The toxic inhibitors (i.e., lead, chromates, etc.) and high VOC contents of these coatings are released during painting operations as organic and toxic air emissions. Federal, state, and local environmental agencies restrict these hazardous emissions through regulations such as the Clean Air and Water Acts, and local Air Quality Management District rules. Chief of Naval Operations (CNO) directives require significant reductions in the Navy's hazardous waste generation of which painting operations are a major contributor. Therefore, it is necessary to develop new high performance coatings which meet environmental restrictions and allow the Navy to continue painting operations.

BENEFIT: The development of non-toxic, VOC compliant coatings will enable the Navy to meet current and future environmental regulations and will reduce the total amount of hazardous waste generated by painting operations. Furthermore, these new materials will eliminate the need for installation of extremely expensive control equipment (i.e., $1M-5M per spray booth for VOC emission control and multi-filter systems for hazardous air pollutants). This effort is in direct support of Navy and Department of Defense hazardous waste minimization policies/directives.

ACCOMPLISHMENTS:

1. The zero-VOC topcoat has been reformulated to address the deficiencies in both pot life and flexibility. This new version is being tested at NAWCADPAX and all MIL-PRF-85285 tests have been completed except for weatherability, stripability, and cleanability.
2. The newest versions of the zero-VOC topcoat are currently being evaluated. The short-term tests show that the majority of the problems stated in June, 1997 have been solved; however, flexibility values are still too low.
3. Service evaluations of PR-1875 (non-chromated, corrosion inhibiting, polythioether sealant) and CA-1000 (non-chromated, non-curing polythioether sealant) on the bulkheads of eight F-18's continue at NADEPs in Cherry Point and North Island. The non-chromate sealants are proving to be satisfactory replacements for the chromate sealants.

TRANSITION: The self-priming topcoat has been authorized for Navy use. This topcoat is currently being implemented at Navy NADEPs. The Environmental Security Technology Certification Program (ESTCP) is funding a demonstration validation of the zero-VOC topcoat at the NADEPs and Warner-Robins Air Logistics Center. This technology is being coordinated with commercial aerospace, coatings, and equipment manufacturers to insure product availability for implementation.

PROJECT SUMMARY

PROJECT TITLE & ID: Laser Cleaning and Coatings Removal; PP-139

RESEARCH CATEGORY: 6.3 Advanced Development

LEAD AGENCY: U.S. Air Force

LAB: Air Force Research Laboratory - Wright-Patterson Air Force Base, OH

PRINCIPAL INVESTIGATOR: Mr. Stephen Fairchild

FY 1998 COMPLETED PROJECT

OBJECTIVE: The objective of this effort is to provide a field demonstration of a prototype laser-based facility to demonstrate environmentally acceptable and cost competitive cleaning and coatings removal from weapon system components. This project will design a self-contained cleaning and coating removal system, design a waste product collection system, and complete preliminary systems engineering. The design will be approved by engineering, the Environmental Protection Agency, and the Occupational Health and Safety Act.

BENEFIT: This project will demonstrate a laser-based coating removal and cleaning process for a wide range of aircraft components having different sizes and materials. The recommended process is expected to be highly cost effective by eliminating the present and future air, solid, and water polluting methods. Thus, it will reduce or eliminate the costs for hazardous stripping of materials, reduce containment costs for solid, liquid and vapor waste streams, and eliminate the legal liabilities associated with waste disposal.

TECHNICAL APPROACH AND RISKS: This effort will implement the technical approach determined in the FY 1993 preliminary design and expand this to a detailed final design. Additionally, this program will fabricate, evaluate, develop, and demonstrate a state-of-the-art automated, controllable coating removal and cleaning system (a repair or remanufacturing cell or process). Various aircraft media controls, robotics sensors, and instrumentation are currently available commercially and may be applied to the system. Software will have to be developed/modified to control the production system. Systems design must incorporate all applicable safety devices and features. The risks with this assessment are associated with availability and adequacy of Air Force, Navy, Army, and industry data. The system will maneuver the laser beam around complex geometries whether on manual or automatic control modes. All effluent gases and particulates will be treated and/or captured. Once the system is built, it will undergo a rigorous confirmation test scheme.

ACCOMPLISHMENTS: The laser and all the accessories was procured in FY 1998. The scope of the project has been changed from an installation specific project to a technology demonstration at the National Defense Center for Environmental Excellence (NDCEE).

TRANSITION: The National Defense Center for Environmental Excellence is in the process of inspecting and installing the Laser cleaning system.

PROJECT SUMMARY

PROJECT TITLE & ID: Advanced Fire Fighting Streaming Agent; PP-158

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Air Force

LAB: Air Force Research Laboratory - Tyndall Air Force Base, FL

PRINCIPAL INVESTIGATOR: Dr. Charles Kibert

FY 1998 COMPLETED PROJECT

OBJECTIVE: This project seeks to identify, evaluate, and validate environmentally and occupationally safe streaming agents that are drop-in replacements for Halon 1211 in wheeled 150 lb. flight line fire extinguishers, in aircraft portable fire extinguishers, and in facility portables. Programs to find a replacement for Halon 1211 were initially directed at chemicals that were available in production quantities. Research indicated that even the most powerful replacements available in these quantities would require 2 to 3 times as much agent as Halon 1211 to extinguish a fire. The best agent from among this group, perfluorohexane, had restrictions placed on it in the Environmental Protection Agency (EPA) Significant New Alternatives Policy (SNAP) listing because of its long atmospheric lifetime. Because of this restriction and an Air Force Civil Engineering/Logistics (CE/LG) re-validation of the requirement for a clean streaming agent, a program to explore several promising families of laboratory scale chemicals was initiated.

BENEFIT: The phase out of ozone depleting chemicals (ODCs) has threatened the ability of the military to provide a powerful, clean means of suppressing fires previously afforded by Halon 1211. The replacements originally developed as substitutes for Halon 1211 have all been caveated for greenhouse warming potential or ozone depletion by the EPA. The Advanced Streaming Agent will be developed from chemical families which have none of these negative global environmental impacts. In addition to the military, the civilian sector, particularly aircraft companies, have had essentially the same problem as the military with regard to the phaseout of Halon 1211. This is a technology that has dual use potential and will serve the needs of multiple sectors of the civilian fire fighting community as well as the three military services and the U.S. Coast Guard.

TECHNICAL APPROACH AND RISKS: Agents from several promising chemical families will be synthesized, then subjected to several key tests to determine their overall suitability: fire suppression effectiveness, limit testing for lethality, storage stability, materials compatibility and global environmental impacts. The agents are expected to emerge from one of four families of chemicals: tropodegradable halocarbon, phosphonitrilics, silicon compounds, or organometallics. As work progresses, additional chemical families will be considered for screening. At each stage of the screening process, failure to meet a given criterion will eliminate a compound from further consideration. Compounds that successfully negotiate the screening will be further tested to determine their lethality and cardiotoxicity levels for use

in obtaining EPA approval. Medium scale fire suppression effectiveness will be determined along with initial delivery system parameters. Quantitative structural activation reaction (QSAR), tissue uptake studies, and pharmokinetic modeling will be initiated. Pilot plant studies to assess large scale synthesis methods will be accomplished. It is expected that 2 to 5 agents may survive the initial screening and testing. The risks for this effort is moderate. It is known that some of the chemicals proposed for testing are 10 to 100 times more powerful as fire suppressants than the Halons with the major unknown being the toxicity of these materials. Consequently, rapid assessment of the toxicity of these substances will be a priority.

ACCOMPLISHMENTS: In FY 1998, several new tropodegradable halocarbon compounds to replace Halon 1211 were identified by developing and employing a Quantitative Structural Property Relationship (QSPR) computer model to predict the compounds that have the powerful fire suppression benefits of Halon 1211 without its high ozone depleting properties (ODP). Candidate replacements have been synthesized and screened for a variety of attributes including effectiveness, compatibility, stability, toxicity, and environmental behavior to ensure suitability as a streaming agent. The QSPR model was successful in identifying blends of octafluoro-2-butene and 1-bromopropane as efficient replacements with low ODP, low tropospheric lifetime and good toxicity properties. Streaming tests of the blends show similar performance to Halon 1211. The QSPR model was also successful in identifying a family of compounds known as brominated unsaturated ethers that are predicted to have excellent fire suppression ability, very low ODP, moderate-to-low toxicity, and several other physical characteristics such as high boiling point and high molecular weight that make them particularly promising. Laboratory scale syntheses have been conducted to verify the predicted reaction rates and yields in order to select compounds that could be produced feasibly and economically in large quantity.

TRANSITION: Successfully screened compounds will be subjected to medium to large scale testing and operational validation by a group of seasoned Air Force/Navy/Marine Corps firefighters (at Tyndall AFB, FL, and Beaufort Marine Air Station, SC). Firefighter exposure data and combustion product interaction information will be analyzed to ensure that the selected compound(s) meet both military and EPA requirements.

PROJECT SUMMARY

PROJECT TITLE & ID: Life Cycle Engineering and Design Program; PP-304

RESEARCH CATEGORY: 6.3 Advanced Development

LEAD AGENCY: Environmental Protection Agency

LAB: National Risk Management Research Laboratory - Cincinnati, OH

PRINCIPAL INVESTIGATOR: Mr. Kenneth R. Stone

FY 1998 COMPLETED PROJECT

OBJECTIVE: The objective is to use lessons learned from the Department of Defense (DoD) cases and other industrial operations Life Cycle Assessments (LCAs) being funded by the Environmental Protection Agency (EPA) to generate a design guide for implementing life cycle principles on environment, performance and cost as an aid to decision-making. This project applies LCA principles to selected DoD operations in order to identify and test potential technical solutions to reduce reliance on toxic chemicals and solvents in industrial and DoD operations.

BENEFIT: The anticipated benefits include the elimination of an EPA 17 chemical, methyl ethyl ketone (MEK), from the radome depainting process, along with volatile organic compound (VOC) emissions. While chemical agent resistant coating (CARC) undergoes tests and reformulation to reduce VOC content, this project shall generate guidance with applicability to facility CARC painting operations DoD-wide. Techniques and product improvements will generate cost savings and operational efficiency.

TECHNICAL APPROACH AND RISKS: With the completion of the base LCAs and technology evaluations for the alternative chemical depainting and the CARC projects, the next step is to conduct an examination of the impacts of these operations on a more detailed level in order to assess the health, ecological, and resource depletion aspects of the alternatives. Two impact assessments are planned: one on CARC painting operations and the second on alternative chemical depainting. In the CARC project, it has been discovered that a painting procedure in the field can vary significantly, depending upon the installations practices. This impact assessment will provide a good comparative basis to test the application of the methodology to distinct, specific sites, providing key information on the validity of our approach. In the case of the depainting study, significant issues have arisen regarding the impacts from the production of constituents, specifically propylene carbonate, n-methyl-pyrolidone and more recently, benzyl alcohol. The impact assessment will focus on these chemicals as components of a solvent formulation, identifying life cycle impacts and documenting the information as a basis for comparison. Another component of the Life Cycle Engineering and Design (LCED) Program is the integration of cost/benefit tools with the LCA methodology. EPA began this component of the study this year as an EPA-funded effort to lay the groundwork for the methodology and submit it for peer review. It will be tested in selected federal operations and will be a component of the final report for the LCED program in 1998. To enhance technology transfer, a lessons learned document will be generated with a full presentation of difficulties

and successes experienced to date.

ACCOMPLISHMENTS: The final year of SERDP funding to the National Risk Management Research Laboratory (NRMRL) resulted in successful completion of the development of a life cycle engineering guide. This document produced by EPA, is the first of its kind for practicing/implementing life cycle assessment principles on environment, performance, and cost as an aid to decision-making. Additionally, environmental profiles of n-methyl-pyrolidone and propylene carbonate as potential alternatives to MEK and methylene chloride in aircraft radome and fuselage depainting have been printed and disseminated by EPA.

TRANSITION: The LCA design guide and the alternatives to MEK, for radome depainting and reduced VOC CARC paint study results are being widely disseminated to DoD field organizations and program managers for future implementation. Additionally, the LCA guidance document will be used to conduct integrated LCAs of DoD and related industrial operations in order to improve design and process efficiencies. This document will demonstrate the experiences of the research team and offer a streamlined approach that reduces the cost of conducting an LCA.

PROJECT SUMMARY

PROJECT TITLE & ID: Extraction and Recycling of LOVA Propellants Using Supercritical Fluid Extraction; PP-660

RESEARCH CATEGORY: 6.3 Demonstration

LEAD AGENCY: U.S. ARMY

LAB: Army Research Laboratory - Aberdeen Proving Ground, MD

PRINCIPAL INVESTIGATOR: Dr. Jeffery Morris

FY 1998 COMPLETED PROJECT

OBJECTIVE: The objective of this project is to demonstrate the scale-up of a process developed for the separation and recovery of RDX from Composition B high explosive. The process, developed on the laboratory scale through previous SERDP support, involves the use of supercritical fluid extraction (SCFE) of the TNT and wax from Composition B. RDX is recovered as a nonextractable material in this process. The process should also be directly applicable to the recovery of HMX from Octol high explosive.

BENEFIT: Project benefits include prevention of pollution associated with the disposal of DoD explosives, and associated reduction of life-cycle costs of munitions. Recycling is an alternative to open burning/open detonation, which is increasingly restricted, and to incineration, which is not widely available and requires size reduction preprocessing. Strat Plan Contribution: Recycle of nitramine (e.g. RDX) and other ingredients from propellant and explosive formulations. The project objective will be realized through the recovery of up tp 10 pounds of RDX from Composition B and up to 3 pounds of HMX from Octol. These recovered materials can be made available for subsequent evaluation by other programs.

ACCOMPLISHMENTS: Initial tests in FY 1998 indicate that processing of up to 300 gram batches of Comp B is feasible. More detailed laboratory studies on the solubilities of TNT and wax in CO_2 as part of the base characterization of Composition B were completed. The NSWC/IHD used new data to define process parameters (temperature, pressure) in its scale-up protocol. Large laboratory scale process studies on Composition B batch sizes of 10 grams and greater have been initiated. Additionally, two open literature publication manuscripts are completed.

TRANSITION: Scale-up of this process will be carried out through a collaboration with the Naval Surface Warfare Center (NSWC) - Indian Head Division. The recovered materials will be made available for subsequent evaluation by other DoD programs.

PROJECT SUMMARY

PROJECT TITLE & ID: Laser Ignition to Replace Chemical Ordnance Igniters for Propulsion; PP-680

RESEARCH CATEGORY: 6.1 Basic Research

LEAD AGENCY: U.S. Army

LAB: Army Research Laboratory - Aberdeen Proving Ground, MD

PRINCIPAL INVESTIGATOR: Dr. Brad Forch

FY 1998 COMPLETED PROJECT

OBJECTIVE: The laser is a non-polluting ignition source that can replace thousands of pounds of hazardous materials in the life cycle of a single armament system. The objective is to: (1) eliminate hazardous components in ordnance (including ordnance manufacturing); (2) reduce the production of waste and unnecessary energetic materials in manufacturing for propulsion systems which includes large, medium and small caliber guns, rockets and missiles; (3) eliminate inventories of lead containing primers (lead styphnate and lead azide); (4) and eliminate hazards in storage and disposal of these components. The long-term goal is to develop a Universal Laser Ignition System (LIS) for propulsion that is free from lead and other hazardous and polluting chemicals.

BENEFIT: The laser is a non-polluting instrument. Hazardous components (i.e., lead containing igniters) in ordnance and ordnance manufacturing are eliminated. A universal igniter for propulsion systems is envisioned. The laser igniter replaces technology that is over 100 years old. The technology provides a safer system for soldiers in the field and numerous performance benefits which include higher firing rates, reduced hazard from accidental ignition from electromagnetic radiation, full computer control of the laser and thus the ignition event, and another completed link in the digital battlefield.

ACCOMPLISHMENTS: Leveraged SERDP dollars have led to the laser being selected as the main igniter for PM-CRUSADER Self-Propelled Howitzer (155 mm XM297 cannon) which is the largest developmental program in the Army. The Program Executive Office - Field Artillery Systems (PEO-FAS) approved the Army to authorize United Defense (largest defense contractor in the world) to build 8 prototype Crusader systems with laser ignition. Representatives from the government of Kuwait traveled to the U.S. in February and negotiations are underway to sell them current production Paladin Self-Propelled Howitzers with laser ignition systems. Laser ignition was demonstrated on the towed 155 mm howitzer at the Army Research Lab (ARL). A M199 155 mm howitzer was fired using the laser with no igniter material and no primer; the propellant alone was ignited. No lead containing primers, pyrotechnics, or other igniter materials were used. Laser ignition was selected as one of the top ten Army Science and Technology projects. Burst fire was demonstrated on the medium caliber 30 mm cannon for the Apache helicopter. Two papers have been accepted for presentation at the Army Science Conference in June. More than 14 Small Business Innovative Research (SBIR) agreements and five Cooperative Research and

Development Agreements (CRADA) were established.

TRANSITION: The Program Manager for the Crusader has already embraced this technology. The results are directly transferrable to other Army, Navy and Air Force systems including PM-Paladin, PM-Apache, PM-Bradley, and Light Forces. A CRADA with Remington Arms has been submitted to transition this technology for use in small arms.

PROJECT SUMMARY

PROJECT TITLE & ID: Recycling Propellants in Nonpolluting Supercritical Fluids: Novel Computational Chemistry Models For Predicting Effective Solvents; PP- 695

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Army

LAB: Army Research Laboratory - Aberdeen Proving Ground, MD

PRINCIPAL INVESTIGATOR: Dr. Betsy Rice

FY 1999 FUNDS: $200K

OBJECTIVE: Waste solid explosives and gun propellants are destroyed primarily by open pit burning or incineration. Extraction and recycling of the propellant using a non-polluting, inert supercritical fluid (SCF) solvent such as CO_2 has economic and environmental advantages. Although the ingredients in composite (nitramine based) propellants are insoluble in CO_2, solubility is enhanced when trace amounts of simple polar modifiers are added to the SCF solvent. The objective of this project is to determine the optimal physical conditions and chemical makeup of an effective SCF CO_2 solvent with added polar modifier using well-established computational chemistry techniques. The technology developed in this project will have application to nitramine-based explosive and propellant formulations.

BENEFIT: The principle benefits include prevention of pollution associated with disposal of Army and Navy explosives and gun propellants and associated reduction of life cycle cost of munitions. Recycling is an alternative to current open burning/incineration of gun propellants which is increasingly restricted.

TECHNICAL APPROACH AND RISKS: Two complementary theoretical investigations on properties and effectiveness of polar modified-CO_2 SCF solvents will be pursued in parallel. The first investigation will focus on the actual dynamic event for dissolution of an RDX crystal in an SCF solvent. Solvation dependence on the physical conditions of the system (far from or close to the critical point of the SCF) will be examined. The second investigation focuses on determining modifier properties that enhance solubility of RDX in the SCF solvent, using rigorous quantum mechanical methods.

ACCOMPLISHMENTS: In FY 1998, Development of the computer model of crystalline RDX was completed, and molecular simulations were performed using the crystal model. The simulations indicated that the model reasonably represents RDX and has a predictive capability for non-reactive processes of this nitramine. The work was published in the Journal of Physical Chemistry, Vol. 101, pp. 798-808, 1997. The model was applied to the new energetic crystal, commonly referred to as CL-20, and found to adequately represent this nitramine crystal. Results of this study are published in the Journal of Physical Chemistry B, Vol. 102, pp. 948-952 (1998). This model also was applied to the explosive HMX published in the Journal of Physical Chemistry B Vol. 102, pp. 6692-6695 (1998)] and 30 nitramine systems

[published in the Journal of Physical Chemistry A Vol. 102, p. 8386 (1998)]. We have found that the RDX crystal model is transferable to other classes of explosives. Tests have shown that the model provides a proper description of 51 non-nitramine crystalline explosives, including nitromethane, PTTN, TNAZ, PETN, TNT, TATB, 1,3,5 trinitrocubane, 1,3,5,7-tetranitrocubane, 1,4-dinitrocubane, 1,2,3,5 pentanitrocubane and 2,6-dinitrohexacyclo(5.4.1) dodecane and 2,2-dinitroadamanate. A manuscript describing the non-nitramine modeling is in review for the *Journal of Physical Chemistry*. The performance of the crystal RDX molecular model in describing different classes of energetic crystals was presented at the 1998 Army Science Conference and was awarded "Best Paper of the Technical Session (Advanced Power and Propulsion Technologies)."

TRANSITION: Results of this effort are being transferred to SERDP's recycling initiative (Project Number PP-660) and other DoD demilitarization and recycling initiative.

PROJECT SUMMARY

PROJECT TITLE & ID: Fluorinated Ship-Hull Coatings for Non-Polluting Fouling Control; PP-756

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Navy

LAB: Naval Research Laboratory - Washington, DC

PRINCIPAL INVESTIGATOR: Dr. Kenneth Wynne

FY 1998 COMPLETED PROJECT

OBJECTIVE: The overall goal of this project was to develop non-polluting, easy fouling release, hull coatings based on flexible, low surface-energy polymers. Ship hull protection from marine fouling organisms is essential for efficient fleet operation and energy conservation. Presently, the Navy standard antifouling coating contains copper as a toxicant. The copper leaching from these coatings represents an environmental hazard and is the subject of increasing regulation which will impact normal fleet operations.

BENEFIT: A non-polluting, easily cleaned coating will be synthesized which will contain no leachable toxics and will have a non-wetting, low-energy surface which resists attachment of marine fouling organisms and permits easy removal of fouling which does adhere. These coatings will benefit all operating vessels and structures and will have obvious commercial application.

ACCOMPLISHMENTS: The fouling release community has recognized that an important "first" has been achieved, namely, the demonstration that fluoropolymer elastomers demonstrate fouling release. Second and third generation fluoropolymer elastomers (fluorinated oxetanes) are being developed toward the goal of "leap-frogging" silicones and providing the "ultimate" fouling release coating. Through a systematic study of surface wetability and stability in water, cure chemistry has been discovered which greatly stabilizes coatings to chemical degradation in water. Preliminary panel testing has been carried out to quantitatively correlate fouling adhesion with surface parameters measured in the laboratory.

TRANSITION: The Naval Sea Systems Command will further test this approach. Additionally, this work, which leverages a number of funding sources and includes industrial and academic collaboration, seeks to transition to market a fouling release coating system that will strengthen the DoD infrastructure in marine materials and ship maintenance and construction.

PROJECT SUMMARY

PROJECT TITLE & ID: Solventless Pyrotechnic Manufacturing; PP-757

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Navy

LAB: Naval Surface Warfare Center - Crane, IN

PRINCIPAL INVESTIGATOR: Dr. Norris Caldwell

FY 1998 COMPLETED PROJECT

OBJECTIVE: The objective of the project is to demonstrate the application of the cast/cure methodology to eliminate the hazardous solvent waste and associated volatile organic compound (VOC) emissions in some important areas of military pyrotechnics manufacture. The cast/cure approach to manufacturing offers the potential for the virtual elimination of the use of volatile solvents in pyrotechnics processing, while still producing the material in a manner that mitigates hazards (ignition) sensitivity.

BENEFIT: With the elimination of hazardous solvent waste and the potential for VOC emissions, expensive solvent recovery and recycling systems would not be needed, and the costs of waste stream treatment would be eliminated. The potential payoff is exemplified by some (projected) procurement figures for FY95: the Department of Defense (DoD) is planning to procure quantities of decoy flares corresponding to a total of about 650,000 pounds of pyrotechnic material, generating from 195,000 to 975,000 gallons of hazardous waste solvent. Based on representative current costs of disposing of waste solvent, annual cost savings from solvent waste elimination alone could be from $2.1M to $10.6M.

ACCOMPLISHMENTS: The efforts on cryo-processing of magnesium/teflon/viton (MTV) resulted in development of a new viton grinding process with novel processing techniques. The cost/benefit analysis performed indicated MTV cost savings of $34 for completed grinding/MTV missing facility at 2000 lb/yr level. One of the technical problems identified in the process: cryo-ground viton does not coat magnesium and could potentially lead to problems in the end-product material. Using the cast/cure processing of decoy flare materials, several rounds of pyrotechnics materials-formulating exercises were carried out, and infrared emission properties of the proposed composition system have been carefully studied. The results of this project were presented at the 1998 JANNAF Propellant Development and Characterization/Safety and Environmental Subcommittees Joint Meeting, 22 April 1998, NASA Johnson Space Center, entitled "The Infrared Emission of Candidate Decoy Materials based on Urethane-Curable Binders (U)" (Paper is CONFIDENTIAL); a companion detailed technical paper has been submitted for publication in meeting proceedings.

TRANSITION: The results of this effort are planned for transition to both a Navy 6.3 Air Expendables program and to Naval Air Systems Command, PMA-272.

PROJECT SUMMARY

PROJECT TITLE & ID: Solventless Manufacture of Artillery Propellant Using Thermoplastic Elastomer Binder; PP-867

RESEARCH CATEGORY: 6.3 Advanced Development

LEAD AGENCY: U.S. Navy

LAB: Naval Air Warfare Center - China Lake, CA

PRINCIPAL INVESTIGATOR: Dr. Thomas Stephens

FY 1999 FUNDS: $300K

OBJECTIVE: The objective is to demonstrate the feasibility of reducing or eliminating the emission of volatile organic compounds (VOCs) and solvents associated with the production of gun propellants by using thermoplastic elastomer (TPE) propellants. New propellant formulations that reduce or eliminate the use of solvents will be developed and evaluated for replacement of current propellants that require solvents to manufacture. Multi-base gun propellant for artillery ammunition creates 0.3 lb of solvent emissions per lb of propellant, and at expected production rates of 3 million lb/yr, this represents the largest source of VOC emissions due to gun propellant production. This project will demonstrate at a pilot plant scale the production of TPE gun propellant by using solventless continuous processing.

BENEFIT: Risk associated with this new technology will be reduced to a level acceptable to program managers without further demonstrations. Once the technology is fully developed and implemented, solvent emissions due to triple-base gun propellant manufacture can be eliminated, including approximately 500,000 lb/yr VOC emissions, 400,000 lb/yr other solvent emissions (contaminated with explosives), elimination of scrap propellant (by reworking propellant in the manufacturing process), cost saving in VOC elimination facility modifications, and elimination of the costs of solvents and of energy costs in heating drying houses.

TECHNICAL APPROACH AND RISKS: New TPE propellant formulations will be designed to permit solventless processing while simultaneously meeting performance and safety requirements. This will require evaluating the most promising TPEs, determining the proper composition and molecular weight of the TPE, and optimizing the choice and amount of oxidizer in the propellant. A solventless manufacturing process will be developed for this propellant by modifying and adapting existing continuous twin screw extrusion technology. Manufacture of the new TPE propellant by the solventless process will be demonstrated at a pilot plant scale. The manufacturability, safety, sensitivity and performance properties of the propellant produced will be evaluated in "proof-of-principle" tests. The main technical risk is that meeting several propellant material property requirements simultaneously may be difficult. In particular, howitzer ammunition requires specific performance characteristics over a wide range of firing temperatures, pressures, and charge loadings; and TPE-based propellants have not been evaluated for a

wide range of conditions.

TPEs will be characterized for viscosity and other physical properties for optimizing binder composition. Small scale (1 to 5 kg) propellant mixes will be prepared and evaluated for solventless processability in initial processing studies that will include capillary viscometry and batch extrusion runs. Viscosity data will be used in numerical simulations of the flow of propellant through the extrusion die. These die modeling calculations will be used to optimize the die design to ensure stable flow and accurate dimensions of the extruded propellant. Initial feeder studies will begin to evaluate methods for handling raw materials and feeding them to the continuous processor. These initial processing studies are required before processing the propellant in the twin screw continuous processor in FY 1998.

ACCOMPLISHMENTS: Based on mechanical property and burning rate data, the BAMO/AMMO formulation of TPEMACS was selected for further development. While awaiting manufacture of propellant for gun firings, BAMO/AMMO mixes were prepared by NSWC Indian Head. Two small mixes were prepared, one from raw ingredients (BAMO-AMMO, RDX, and HBNQ) and one from existing propellant containing BAMO-AMMO and RDX into which HBNQ and additional BAMO-AMMO were mixed. Material from both mixes underwent safety testing, and the results were satisfactory. Eight lb of propellant were prepared by reformulating BAMO-AMMO/RDX propellant as described above and measured the viscosity by using capillary viscometry. The flow behavior appeared to be satisfactory and qualitatively very similar to the original BAMO-AMMO/RDX propellant. This provides some indication of the potential for recycling (or reformulating) TPE propellants.

TRANSITION: To leverage the cost of testing and evaluation, this project will be closely coordinated with efforts to develop a propellant charge for the Crusader 155-mm howitzer. Data on new propellants developed under this project will be provided to the Program Executive Officer (PEO) for Field Artillery Systems to choose a new solventless propellant formulation to fully develop and qualify for field use. Solventless propellant processing technology developed under this project will be transferable to other gun propellant programs.

PROJECT SUMMARY

PROJECT TITLE & ID: Trapped Vortex Combustor for Gas Turbine Engines; PP-1042

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Air Force

LAB: Air Force Research Laboratory - Wright-Patterson Air Force Base, OH

PRINCIPAL INVESTIGATOR: Dr. W. M. Roquemore

FY 1999 FUNDS: $250K

OBJECTIVE: The goals of this project are to demonstrate the feasibility of developing a Trapped Vortex (TV) combustor that will: (1) reduce aircraft pollutant emissions [nitrogen oxides (NOx), volatile organic compounds (VOCs), CO, and particulate matter (PM)-10] by 60 percent, bringing them significantly below the proposed 1996 Environmental Protection Agency (EPA) regulations, and (2) reduce NOx emissions by 60 percent, bringing them below the 1995 EPA regulation for land and marine based gas turbine engines burning distillate fuels. Since the total amount of emissions from gas turbine engines is directly proportional to the amount of fuel consumed, a 3 percent savings in fuel will also result in a 3 percent reduction in emissions. Since aircraft spend most of their time at high altitudes, a 3 percent reduction in total emissions would reduce global environmental changes due to NOx reduction of ozone in the stratosphere and the greenhouse effect of CO_2 and H_2O emitted from high flying aircraft.

BENEFIT: This project will provide the basis to demonstrate the capability of TV combustors to reduce pollutant emissions and conserve fuel. The environmental objective is to reduce NOx, VOCs, CO, and PM-10 aircraft emissions to 60 percent below the proposed 1996 EPA aircraft emissions regulations and to reduce NOx emissions by 60 percent below the California Resource Board recommendation of 42 ppm for L&M based gas turbine engines burning distillate fuels. The environmental impact of only military aircraft using the TV technology that meets the project goals would be enormous. For example, assume that all existing military aircraft had a TV combustor. The VOCs for the Air Force and Naval bases would drop by a factor of 10 in some cases and the NOx emissions would be reduced by 20 percent to 40 percent depending on the aircraft at the bases. This would permit flight operations and training to continue at current levels with reduced or even eliminated fines due to pollutant emissions from aircraft. If commercial aircraft also had TV combustors, then the environmental and cost impact improves by a factor of 8, since in the U.S. commercial aircraft uses about 88 percent of the jet fuel consumed annually.

TECHNICAL APPROACH AND RISKS: The project will develop an optimized trapped vortex design for use in the General Electric Integrated High Performance Turbine Engine Technology (IHPTET) Phase III prototype gas turbine engine and will evaluate the use of a trapped vortex combustor for reducing NOx emissions in stationary gas turbine engines used on-board Naval vessels for power generation. Three parts are required to make this new combustor system: a new integrated fuel injector/diffuser, TV combustor

section, and thermal management system. General Electric (GE) in conjunction with the IHPTET program will design and test the integrated diffuser and thermal management system. GE and Air Force Research Laboratory (AFRL) will work together on this SERDP project to design and incorporate the low emissions TV combustor portion and will incorporate all three efforts into a final design. The technical approach uses a combined Computational Fluid Dynamics (CFD) design study with an experimental sector rig study to investigate different TV configuration at realistic conditions and with realistic size combustors. TV combustors with three different missions will be investigated. The first mission corresponds to a future high performance aircraft that would utilize IHPTET engine technology. The second mission corresponds to that of a conventional aircraft. This mission is included to provide the Air Force with the option of upgrading existing engines to a low emissions, fuel efficient TV combustor in the future. The third mission corresponds to possible future forward-fit for new purchases of LM2500 engines used aboard Naval vessels.

ACCOMPLISHMENTS: The following accomplishments were achieved in FY 1998:
1. Evaluated 17 cavity designs and used the results to establish design rules for Trapped Vortex Combustors.
2. Designed and fabricated 4 TVC sectors for test in the PRSC Rm20 High Pressure Combustion Tunnel Facility.
3. Completed fabrication and check-out of the PRSC Rm20 High Pressure Combustion Tunnel Facility
4. Obtained excellent results in the evaluation of the Tri-Passage IDIF and Double Vortex Cavity sector tests in the PRSC Rm20 High Pressure Combustion Tunnel Facility.
5. Engine temperatures were reduced by as much as 500°C resulting in decreased NOx emissions.
6. Demonstrated feasibility of the Trapped Vortex Combustor concept at realistic high pressure and high temperature conditions.

TRANSITION: Full-scale tests will be performed at GE Aircraft Engines/Allison ADC with the optimized TV combustor in a full-scale prototype IHPTET. The TV combustor is targeted for the following future planned products: (1) a new high performance aircraft engine; (2) retrofit for upgrading existing engines; and (3) forward fit of new LM2500 engines for Naval vessels.

PROJECT SUMMARY

PROJECT TITLE & ID: Pesticide Reduction through Precision Targeting; PP-1053

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: Department of Agriculture

LAB: Imported Fire Ant & Household Insects Research Unit - Gainesville, FL

PRINCIPAL INVESTIGATOR: Dr. Richard Brenner

FY 1999 FUNDS: $260K

OBJECTIVE: The Department of Defense (DoD) presently uses approximately 1 million lbs of pesticide active ingredient annually, excluding pesticides used during major deployments. In each of these settings, these pests and disease vectors also affect the health of DoD personnel by transmitting pathogens, contaminating foods and surfaces with biologics, and producing allergens. The overall research goal is to reduce pesticide use and risks through the use of precision targeting and comparative risk reduction. This will result in the development of a comprehensive, standardized, verifiable, and documentable system for protecting troops, DoD supplies, and DoD facilities from disease vectors and pests in a manner that reduces pesticide use and risk. This novel precision targeting approach to integrated pest management (IPM) will reduce pollution from pesticides while ensuring control of disease vectors and pests that impact military readiness in three major settings: (1) in military deployments and training exercises, vector-borne diseases, such as malaria, leishmaniasis, dengue, and tick borne illnesses transmitted by mosquitoes, flies, and ticks, cause direct loss in troop combat effectiveness; (2) in the DoD supply system and in DoD supply depots, stored products pests and other pests cause losses to war stocks of military rations and other material such as uniforms and blankets with losses increasing during longer storage times; and (3) on military installations, a wide range of pest species cause damage to buildings, structures, and vegetation.

BENEFIT: Successful execution of this research will, for the first time, provide standardized procedures for achieving comparative risk reductions associated with the broad scope of disease vectors, pests, pesticides, and pesticide resistant populations in military theaters of operation as well as on military installations. Specific payoffs include reduced use of pesticides by as much as 40-80 percent depending on pest problem via a comprehensive, standardized, verifiable, and documentable system and reduced direct and indirect costs of pesticides.

TECHNICAL APPROACH AND RISKS: This research is designed to meet these unique DoD needs by providing sophisticated surveillance of disease vectors and pests combined with a novel process of "precision targeting" selected interventions. Precision targeting is a functional strategy allowing incorporation of independent IPM tools. However, additional research is needed to develop the precision targeting concept further into a standardized, quantifiable risk assessment computer program for determining the necessity of interventions and selection of those that will optimize reduced use of

pesticides, risk reductions, and cost effectiveness (comparative risk reduction).

Project research will focus largely on developing a comparative risk assessment model based on spatial probabilities that incorporate techniques of monitoring and detecting pests and risks, and on proving the concept and process for versatile field-use by relatively untrained personnel. Few technical difficulties should be encountered because the project's research team has diverse expertise that is capable of executing this complex mix of basic and applied research, in part due to existing United States Department of Agriculture (USDA) funding. This project leverages existing scientific expertise within USDA Center for Medical, Agricultural, and Veterinary Entomology (7-9 scientists) with technical support and equipment made possible through the SERDP funding to address this important unique DoD issue of preventing pollution while safeguarding supplies, facilities, and personnel from disease vectors and pests.

ACCOMPLISHMENTS: Methods and algorithms have been finalized, using standard ArcView™ GIS tools, for conducting comparative risk reductions. These allow the use of a computer program to determine the necessity for, and selection of, an intervention that will optimize pesticide-use, risk and cost. The application of this tools/concept is projected to reduce the pesticide use by 40 to 80 percent resulting in both direct and indirect savings to DoD. Beta tests of this SERDP sponsored software/hardware tool conducted at US Army Center for Health Promotion and Prevention Medicine (CHPPM) golf course site in Ft. Meade MD for treatment of June Beattle Larvae indicated that pesticide use can be reduced by 67 percent and would represent $136 in possible labor and pesticide per fairway. Protocols have been completed for the integration of typical toxicology and exposure data on biocides (obtained from the U.S. EPA) with spatial patterns of land-use and human activity.

TRANSITION: Following successful development and testing of this concept, full documentation will be presented to the Armed Forces Pest Management Board for possible expansion to other pests and DoD operations, thereby resulting in the greatest possible reduction in pesticide use.

PROJECT SUMMARY

PROJECT TITLE & ID: Low VOC Chemical Agent Resistant Coatings (CARC); PP-1056

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Army

LAB: Army Armament Research, Development, and Engineering Center - Picatinny Arsenal, NJ

PRINCIPAL INVESTIGATOR: Mr. Robert Katz

FY 1999 FUNDS: $950K

OBJECTIVE: This project will develop a low volatile organic compound (VOC) Chemical Agent Resistant Coating (CARC) system suitable for use on military equipment in which the materials and processes for the reformulation/application, stripping, and disposal are optimized and in compliance with current and anticipated regulatory requirements. The primary focus is to reduce the VOC of the polyurethane topcoat from 3.5 lb/gal to 1.8 lb/gal. A secondary objective will be to eliminate the hazardous air pollutants (HAPs) and toxic solvents used in the current topcoat formulation.

BENEFIT: At current annual usage nationwide, estimated to be 3 million gallons per year, a CARC targeted to a 1.8 lb/gal VOC limit would save at least 5 million pounds of VOC per year in the application of the coating, proportionately reduce photochemical smog generation and avert Notices of Violation (NOVs) at user facilities including depots, air logistic centers (ALCs), bases, and original equipment manufacturers. Those VOCs which would be reduced or eliminated include: methyl isobutyl ketone, methyl isoamyl ketone, toluene, xylene, and butyl acetate, all of which are HAPs.

Furthermore, the technology developed by this project will eliminate the need to install emission control devices for approximately twelve facilities for a total cost avoidance of $60 million for equipment installation and $3 million saved in annual operating costs. By developing one CARC topcoat for use by all the services substantial savings will result in procurement and logistics operations.

TECHNICAL APPROACH AND RISKS: The technical approach for the reformulation work will focus on high performance, water reducible (WR) polyurethane binder systems which have the potential for chemical agent resistance and meets the performance requirements of the Army, Air Force, and Marine Corps. Candidate polymers will be obtained from raw material suppliers, screened for live agent resistance, and formulated into camouflage topcoats. Requirements for the WR CARC will include compatibility with current camouflage pattern painting procedures and universal use under all current and foreseen VOC regulations.

The approach to the stripping work will be to focus on evaluation of currently used methods of removal to optimize the processes for de-painting and disposal of the CARC developed under this project. A review

will be made of current technology including those projects conducted by: the National Defense Center for Environmental Excellence (NDCEE), the Joint Depot Environmental Panel (JDEP), the three services under the SERDP; as well as a review of existing CARC stripping operations at depots, original equipment suppliers and other manufacturing/maintenance facilities. Selected technologies will then be tested to determine the applicability to strip the new CARC as applied to a variety of substrates (aluminum, steel, composites). Processes will be adjusted to permit the optimum utilization of technologies to minimize environmental impacts of the stripping and disposal operations consistent with economical operations at the manufacturing and maintenance facilities. Emphasis will be given to non-chemical means of stripping due to the large quantities of hazardous wastes which are generated by the use of chemicals.

ACCOMPLISHMENTS: Initial pilot lot quantities of the water reducible tri-service CARC were produced by the paint industry partner, Hentzen Coatings. Properties of the pilot lot material have been verified with the exception of chemical agent resistance testing. All of the non-film characterization tests were completed by the Carderock-Phila Division of the Naval Surface Warfare Center (CD-NSWC). These tests include: freeze thaw stability, accelerated storage stability, solids content, volatile content, flash point, density, fineness of dispersion, viscosity and pot life. The application process/film performance related design of experiments (DOE) was initiated.

The Air Force Research Lab, Materials and Manufacturing Directorate, prepared panels of aluminum, steel and fiberglass composite materials for stripping tests. Fabrication and accelerated aging of initial batches of the current CARC and of the water reducible SERDP CARC have been completed. Testing was conducted on aluminum and steel panels coated with the standard CARC and the SERDP Low VOC CARC using several chemical strippers currently being used by the depot community. There was no difference in the removal rates between the SERDP Low VOC CARC and the standard CARC. Dry media removal testing is currently under way using steel shot, garnet and plastic media blasting.

TRANSITION: Two depots — Letterkenny Army Depot, PA and Anniston Army Depot, AL — will host field demonstrations of the new coatings application under different environmental and seasonal conditions. Subsequently, vehicles will be shipped to various locations for extensive, severe field service performance evaluation.

PROJECT SUMMARY

PROJECT TITLE & ID: Eliminate Toxic and VOC Constituents from Small Caliber Ammunition; PP-1057

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Army

LAB: Army Armament Research, Development, and Engineering Center - Picatinny Arsenal, NJ

PRINCIPAL INVESTIGATOR: Mr. Wade Bunting

FY 1999 FUNDS: $600K

OBJECTIVE: The objective of this program is to develop non-toxic small caliber ammunition which will meet U.S. and North Atlantic Treaty Organization (NATO) performance standards for all calibers (5.56 mm, 7.62 mm, 9 mm, .50 caliber). This effort will focus on eliminating toxic components in the projectile core, primer, and manufacturing processes. All proposed solutions must be economical and feasible while meeting all environmental regulatory guidelines and standards over the life cycle of the cartridge.

BENEFIT: This project will develop a non-toxic cartridge that will eliminate the environmental and hazardous effects that are associated with current ammunition. It is anticipated that approximately $2.5 million required for waste removal at each outdoor firing range as well as the $100K annual cost for lead contamination monitoring will be eliminated. Furthermore, the 601 indoor National Guard ranges currently closed will no longer require $150K/each in upgrades to become operational, thereby saving $90 million. Lake City Army Ammunition Plant costs will be reduced by $100K per year from elimination of lead sludge treatment.

TECHNICAL APPROACH AND RISKS: Projectile core: The approach is to conduct the appropriate environmental studies of candidate projectile core materials to ensure their viability for use in non-toxic projectiles, and provide methods by which the recovery of the material is optimized and release is minimized. Environmental testing will include leaching, corrosion, and biological uptake studies to determine the form chemistry, mobility, and uptake of unrecoverable materials. These results will provide guidance for optimizing the environmental stability and thus maximizing recovery and recyclability of the next generation of projectile materials. The major areas of concern for projectile core replacement are the terminal ballistic performance (lethality/penetration) and mobility/toxicity of materials. In addition, the final candidate must also conform to all bio-uptake requirements.

Cartridge primer: This effort will utilize a new class of non-toxic energetic materials called metastable interstitial composites (MIC) as a replacement for current primer materials which include lead styphnate, barium nitrate, and antimony sulfide. A MIC material is an engineered energetic consisting of two or more chemical species that are exothermically reactive with each other. There are three areas of concern for

replacement of current primer materials. First, the MIC compounds have never been used in small arms percussion primers. Second, the temperature output from the MIC composition upon ignition must be verified. Third, performance of these materials when subjected to high rates of fire such as in a minigun, must be investigated.

ACCOMPLISHMENTS: The following accomplishments were achieved in FY 1998:

1. Bullet: The investigation of the chemical stability and mobility of tungsten as contained in non-lead bullets continued this period. The environmental stability and mobility of the powdered tungsten as part of fragmented bullets is being examined employing combinations of leaching and aging (corrosion) experiments. Materials to be used in the non-lead bullets are being exposed to simulated environments (soil, solvents, temperatures, etc.) to determine which compounds will be formed and examine their solubility and mobility. A set of leaching experiments utilizing sand and simulated acid rain has been completed.
2. Primer: Continued to fabricate M41-style MIC-based primers at Los Alamos National Laboratory for pressure-versus-time cartridge tests at the Army Armament Research, Development, and Engineering Center (ARDEC) / Picatinny. An example of the tests is a study in which it was shown that fast-burning MIC materials are required to achieve relatively prompt ignition of the cartridge propellant. In the tests, the performance of a "fast-burning" MIC was compared with the performance of a slower-burning MIC. The "fast-burning" MIC consisted of material that exhibited a characteristic loose-powder burn rate of 760 meters/second, whereas the slower-burning MIC exhibited a burn rate of 560 meters/second. The difference in the MIC burn rates is attributed to an increased average particle size for the aluminum particles in the slower-burning MIC. A time delay of up to several additional milliseconds to achieve peak cartridge pressure was observed for primers that were fabricated using slower-burning MIC compared with that for primers that were fabricated using "fast-burning" MIC. This observation is important in that it underscores the necessity of maintaining relatively tight process control during the fabrication of MIC materials that are to be used in percussion primers. Use of MIC materials that exhibit slightly reduced loose-powder burn rates results in significant degradation of primer performance.

TRANSITION: ARDEC, the lead laboratory for the ammunition Single Manager, will work with industry to facilitate transition of results into fieldable products.

PROJECT SUMMARY

PROJECT TITLE & ID: Elimination of Toxic Materials and Solvents from Solid Propellant Components; PP-1058

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Army

LAB: Aviation and Missile Command - Huntsville, AL

PRINCIPAL INVESTIGATOR: Dr. Robert Stanley

FY 1999 FUNDS: $1330K

OBJECTIVE: The overall goal of the "Green Missile" program is the elimination of major sources of toxic/hazardous materials used in solid rocket propulsion systems. The objectives are three-fold: 1) develop lead-free extrudable and castable propellant for minimum smoke systems; 2) develop complete and clean, HCl-free, combustion of propellant; and 3) develop solventless methods for processing energetic oxidizers.

BENEFIT: Immediate benefits from the research are: 1) a lead-free formulation for HELLFIRE and the Tri-Service 2.75 rocket, solving 95 percent of the current lead emission problems; 2) an HCl-free formulation for the TITAN, solving 25 percent of the total HCl emissions; and 3) a solventless energetic oxidizer process for HELLFIRE, a solution for 60 percent of the AND/CL-20 systems. With technology transfer to similar systems, the potential overall cost savings from the research are $1.5M from lead elimination and $3M with solvent elimination/minimization.

TECHNICAL APPROACH AND RISKS: Extrudable and castable formulations of ammonium dinitramide (AND), CL-20, or AN, rocket motor propellants will be developed. The associated energetic polymeric binders, including thermoplastic elastomers (TPEs) developed by the Clean Agile Manufacturing of Energetics (CAME) program (SERDP Project PP-063), will also be evaluated and selected for development with the candidate formulations. Data from the characterization of the final formulations shall be compared to baseline data to determine the amount of pollution prevention obtained using the new formulation and that the user requirements are still being met. Technology demonstrations will be done for the Tri-Service 2.75 and Army's HELLFIRE systems.

Propellant formulations containing ultra-fine aluminum (UFAL) and non-halogenated oxidizers will be developed and characterized. Formulation studies shall be conducted to determine the optimum processing procedures. The combustion efficiency shall be determined as well as the identity of the combustion products to demonstrate clean burning.

A method to produce comminuted AND, CL-20, and AN oxidizers in a size, shape, and purity suitable for propellant manufacture will be developed. Process parameters that influence the behavior of these solvated oxidizers, when crystallized in a liquefied gas antisolvent, will be evaluated and optimized. Included in these evaluations will be the effects of atomization droplet size, nozzle configuration, oxidizer concentration, solution viscosity, and liquid surface tension on particle size and structure. Process scale-up will be demonstrated with materials to be used for the 2.75 and HELLFIRE systems. Supercritical fluid processing of energetic components will be achieved through supercritical chemistry, supercritical processing and energetic material processing. Technology demonstrations will be done with AND/CL-20.

The technical risk associated with the research is that the alternative materials that are developed may be environmentally friendly but not have the necessary propulsion characteristics. Critical factors include particle size, bonding agent compatibility, and stability.

ACCOMPLISHMENTS: Alternatives for lead as a ballistic catalytic have been identified for both castable and extrudable formulations. Approaches evaluated include castable processing using bismuth compounds, lead free minimum smoke propellant compositions containing oxidizers such as A DN filled double-base minimum smoke formulations which are extruded and the extruded composite minimum smoke approach. Eliminate HCL: Preliminary tests showed improved combustion using UFAL and than with and aluminum. Propellants containing more than 10% UFAL were difficult to readily process, but propellants made with a blend of UFAL and conventional aluminum were readily processable, even with a total aluminum content as high as 20%.

Parametric characterization for solventless processing was completed. Droplet residence time in liquid CO_2 was found to influence particle morphology. Oxidizer concentration has minimal effect on particle size. For nozzle configuration, impingement is superior to fan type. Slower feed rates reduced accretion and generated smaller, smoother crystals. Scale-up to 1 pound quantities was completed.

TRANSITION: Program Managers/Program Executive Officers for HELLFIRE, Tri-Service 2.25 rocket and TITAN are prepared to endorse this technology when successfully demonstrated.

PROJECT SUMMARY

PROJECT TITLE & ID: Next Generation Fire Suppression Technology Program; PP-1059

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: National Institute of Standards and Technology

LAB: Building and Fire Research Laboratory - Gaithersburg, MD

PRINCIPAL INVESTIGATOR: Dr. Richard Gann

FY 1999 FUNDS: $3,500K

OBJECTIVE: Halon 1301, the predominant and critical total flooding fire suppressant installed in weapons systems, is no longer in production due to its deleterious effect on stratospheric ozone. The objective of this program is to develop and demonstrate, by 2004, environmentally acceptable and user-safe processes, techniques and fluids that meet the operational requirements currently satisfied by Halon 1301 systems in aircraft, ships, land combat vehicles, and critical mission support facilities. The results will be specifically applicable to fielded weapons systems and will provide dual use fire suppression technologies for preserving both life and operational assets. This effort leverages prior SERDP-funded research and the Research Development, Test, and Evaluation (RDT&E) infrastructure created under the ongoing Department of Defense's (DoD's) near-term research program.

BENEFIT: The outcome of this program will be demonstrated alternatives to Halon 1301. This will enable DoD weapon system managers to removing their dependence on a key ozone-depleting substance while minimizing fiscal and operation barriers to implementation.

TECHNICAL APPROACH AND RISKS: The research approach consists of six parallel Technical Thrusts, closely integrated to achieve specific milestones within an 8-year time frame. This approach was developed collaboratively by government, industry, and academic experts in fire science, the contributing technical disciplines, instrumentation, testing, and Halon 1301-protected weapon systems. Following are the six Technical Thrusts, which embody 24 separate research elements.

1. Risk Assessment and Selection Methodology develops a process for choosing among alternative technologies by applying modern decision-making concepts.
2. Fire Suppression Principles establish the mechanisms of flame extinguishment using detailed experimental studies and computational models leading to new approaches for fire control.
3. Technology Testing Methodologies select, adapt, and develop test methods and instrumentation to obtain data on the effectiveness and properties of new suppression approaches.
4. New Suppression Concepts define new ideas for fire suppression based on chemical and physical principles.
5. Emerging Technology Advancement accelerates a variety of processes, techniques, and fluids that are currently under development.

6. Suppression Optimization develops the knowledge to obtain the highest efficiency of each candidate technology.

This is a "living" program, representing the best current thinking for achievement of the objective, yet adaptable as the knowledge base grows. There are always risks in such an undertaking. For instance, there might be no chemicals that perform well for all the desired properties; no new fire suppression technologies might emerge; optimization principles might not improve mediocre approaches sufficiently; and lab-scale measures might not adequately predict real-scale performance. This research is designed to provide the scientific understanding to maximize the likelihood of overcoming risk factors.

ACCOMPLISHMENTS: Sixteen new start projects were initiated in FY 1998. The NGP program has now its own web page (http://www.dtic.mil/ngp). Following are some of the significant accomplishments from FY98 work:

Data on fires in military platforms and the outcome of these fires were received from military safety centers and a draft report summarizing these was completed. A number of compounds containing such atoms as phosphorus, iron, nitrogen, and bromine, have been demonstrated to be at least as effective as halon 1301 with little potential environmental impacts. These families of chemicals are being examined to identify members with other desirable properties, and studies of more families are in progress. New concepts for high efficiency powders have been proposed and are being pursued. These are promising for the platforms for which a perfectly clean agent is not deemed essential.

Assessment of the toxicity of candidates is being modified to include maximum realistic exposures to the chemicals. This may well allow reconsideration of some effective suppressants that were previously regarded as too risky. A new apparatus developed under the NGP can measure the effectiveness of gaseous, liquid droplet or mist, and (soon) powdered agents using only small samples. This enables quick examination of new, custom compounds with properties not previously accessible, such as liquids with high boiling points. Current research is defining the penalties imposed by different types of clutter, enabling more careful definition of desirable agent properties and distribution system design. Example: Flames in a cavity are more stable than flames stabilized downstream of a single bluff-body.

Enhanced capability for monitoring the dispersion of the agent and the undesirable combustion products (*e.g.*, HF) during quenching of fires in actual weapons systems is suggesting new directions for improvement, such as the identification of new gelling agents for powders. Additionally, characterization of the particle behavior in flames as function of the individual size groupings and position of the flames of various strain is underway and fabrication of wind tunnel for flame spread experiments is completed. A successful workshop on screening methods for agent compatibility with people, materials, and the environment was held. A detailed summary of the discussions and conclusions from the workshop is available online at http://flame.cfr.nist.gov/ngp.

TRANSITION: This is an eight-year, comprehensive research and development (science and technology) effort with leveraged funding from all DoD Services, industry, and academia. Successful sub-projects will be further developed within this program. "Spin offs" to various weapons systems development programs are anticipated.

PROJECT SUMMARY

PROJECT TITLE & ID: Tri-Service "Green" Gun Barrel - A Physical Vapor Deposition for the Application of Environmentally Safe Coatings for Gun Barrel Bore Protection; PP-1074

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Army

LAB: Benet Laboratories - Watervliet Arsenal, NY

PRINCIPAL INVESTIGATOR: Dr. John Vasilakis

FY 1999 FUNDS: $850K

OBJECTIVE: This project will develop an innovative dry (non-aqueous) process for the deposition of chromium or other materials equally suited for the bore protection of a gun barrel to replace the aqueous electrodeposition process. This novel (non-aqueous) non-polluting process is called the Cylindrical Magnetron Sputtering Process. The project will evolve the applied research and develop the appropriate technology culminating in an advanced technology demonstration addressing specific Army, Navy, and Air Force requirements in the plating of the Medium Caliber Barrels. Moreover, it will show that the work can be spun off to Large Caliber Gun Barrels and other applications including cylinders for: recoiling mechanisms, aircraft landing gear, the oil processing industry, the power generation industry, and the mining and exploration industry.

BENEFITS: Current weapon systems and those being developed or in the planning stage today will have gun tubes with chromium as a protective deposit on their interior/bore surface. This protective cover protects the bore surface against the harsh environment of the hot propellant gases, and the mechanical effects of the projectile thereby increasing the life of the gun tube. However, chromium is a heavy metal which is deposited onto the tube surface using aqueous electrodeposition. The chromic acid used in the deposition process is a hazardous substance because it contains hexavalent chrome. Hexavalent chromium, in the aqueous liquid and misting forms, is a known carcinogen which is extremely expensive to dispose of because of its toxic nature. For FY95 for large caliber barrels, the cost of waste water treatment and sludge removal was $2.3M. This was for only one year and does not include the cost of medium caliber gun tubes.

This program will develop a dry, environmentally clean replacement process for the existing aqueous electrodeposition chromium plating facility. All the services will benefit, including not only those who plate in-house, but also the industrial partners who are producing many of the weapons on contract.

TECHNICAL APPROACH AND RISKS: The solution to the aforementioned environmental problems is the substitution of the Cylindrical Magnetron Sputtering (CMS) for the present aqueous electroplating

process. CMS is a dry, environmentally clean technology capable of depositing chromium on gun tubes. It also has the flexibility to deposit other refractory metals and their alloys as well as being able to tailor the coating properties through the deposition thickness. Although the environmental focus is on chromium, alternate materials such as tantalum, which will eliminate environmental problems all together as well as providing improved bore protection, will be evaluated. If chromium were deposited, environmental problems can still exist because a "consumable" chromium target would have to be made, most likely, by the same electrodeposition process that this project seeks to eliminate.

Initial efforts will focus on developing the facility for investigating a single medium caliber size and the parameters required for depositing a well-adhered, uniformly-coated tubular section. Once established, the facility will be sized to accept the different caliber gun tubes provided by the tri-Service partners. These will be returned to the partners for firing tests. Results of the tests will be evaluated by the coordinating laboratory in conjunction with its partners. Leveraged support is through universities, other government agencies, and industries. Some of this support is through additional funds while other support is through exchange of services. Where necessary, Cooperative Research and Development Agreements (CRADAs) will be developed if non-existent. These areas cover novel efforts in coating evaluation and coating property determination, mathematical modeling of the experimental efforts, the providing of gun tubes for coating, etc.

ACCOMPLISHMENTS: Preparation of the two prototype test beds for demonstrating the CMS process for both the 25mm 6" laboratory tests and the full size M242 Bushmaster are continuing. Additional runs were made on the 45mm test-bed. There was improvement in the ability to deposit the coating at a lower inert gas pressure and a denser coating was developed. An examination of the coating structure shows the densification of the coating as the pressure is lowered. EPA continued its role in conducting the Life Cycle Analysis. All material for the analysis was CMS transmitted to them.

A preliminary finding indicates that the inert gas pressures used in the CMS facility can be related to the Planar Magnetron Sputtering fixture in a 3 to 1 ratio. This is significant as it is easier to demonstrate advances in the planar system and then transition them to the CMS system.

TRANSITION: There is tri-Service support for the program and typical medium caliber barrels from each of the Services will be coated with the new process and test fired at each of their respective facilities. The program is also heavily leveraged with others from not only the environmental area, but also from gun barrel wear and erosion areas. Industry has provided information to the program regarding environmental costs and have indicated interest in applying the technology once it has been developed.

PROJECT SUMMARY

PROJECT TITLE & ID: Replacement of Non-Toxic Sealants for Standard Chromated Sealants; PP-1075

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Air Force

LAB: Air Force Research Laboratory, Wright Patterson Air Force Base - Dayton, OH

PRINCIPAL INVESTIGATOR: Alan J. Fletcher

FY 1999 FUNDS: $390K

OBJECTIVE: The objective of this work is to formulate and test candidate replacement non-chromated sealants that will provide equivalent or improved properties to those currently maintained by existing chromated sealants while meeting the requirements of MIL-S-81733C. In addition, the volatile organic compound (VOC) content of the materials will be significantly reduced, with a reduction goal of 65 percent.

Numerous chromated sealants are required in aircraft systems and on weapons to provide protection against corrosion, prevent moisture entry, provide a fuel barrier, and provide electrical insulation. All of these sealants use chromium as the primary corrosion inhibiting substance, which has been designated as hazardous and is targeted for removal to comply with either current or pending Occupational Safety and Health Administration (OSHA) requirements. Most also contain VOCs such as methyl ethyl ketone (MEK) and toluene. One million pounds of chromated sealant must be disposed of by DoD each year. Given an average disposal cost of $1.50 per pound, $1.5 million is spent on disposal alone. Additionally, reclaim facilities at depaint/deseal facilities at the major depots cost millions to construct and operate.

BENEFIT: The benefits of this project are four-fold: 1) reduced use of hexavalent chromium and VOCs; 2) development of longer shelf-life sealant formulations; 3) development of primerless sealant formulations; and 4) expansion of enabling technology to replace other chromated sealants.

TECHNICAL APPROACH AND RISKS: The sealants industry has been researching and developing new chrome replacement products for several years. This proposed team has played a major role in establishing program objectives and requirements, providing formulation guidance, testing of new materials, and technology transition. Under the team's guidance, one new chromate-free corrosion inhibiting sealant has been developed, tested and transitioned to the field. However, additional work need to be done. Replacement for only one class of material has been accomplished so far. There are many more types and classes of materials that need to be developed. Recent advances in polymer chemistry provide a way to develop drop-in replacement materials. This new polymer has some properties that are very beneficial to corrosion-inhibiting sealants such as rapid cure times without reducing work life, a

pleasant odor, excellent rheological properties, excellent cure at low temperatures, and high solvent resistance. Therefore, the work proposed herein is directed towards utilizing this new polymer to formulate corrosion inhibiting sealants for all the types and classes of MIL-S-81733.

Task 1–Polymer Selection and Optimization: This task will select, develop and optimize the base polymer system to be used for formulation development. The end result of the task will be a base polymer system that can be used to formulate non-chromated corrosion inhibiting sealants.

Task 2–Selection of Curing Agents: This task will research, develop and formulate curing agents for the base polymers systems selected. A contract will be awarded to the sealant manufacture from Task 1 to research and develop curing agents for the base polymers systems selected. These curing agents will be non-chrome and minimum VOC compounds that provide the best curing mechanism.

Task 3–Selection of Corrosion Inhibitor: This task will research, develop, test and optimize non-chromated corrosion inhibitors. A contract will be awarded to sealant manufacturers that have successfully completed Task 2 to research, develop and optimize corrosion inhibitors for their sealant system.

Downselection of Sealant Systems: This task will downselect to one sealant system for the two major sealants needed. The requirement for each type and class of product will be reviewed by the team and the selection of one sealant system will be made for formulation into a sealant material that will meet the requirements for the intended use of each type and class of material.

Task 4–Formulation of Sealant Compounds: This task will formulate sealant compounds needed to replace two of the types and classes found in MIL-S-81733.

Task 5–Formulation Testing: Laboratory or pilot plant batches of each formulation will be tested for the critical requirements of type and class or sealant. Material samples will be provided by the sealant manufacturers to the Air Force Research Laboratory, the Naval Air Warfare Center, and the Army Research Laboratory. These laboratories will test the formulations to the critical requirements of each service.

Task 6–Candidate Optimization: This task will optimize the promising formulations and will include optimization for ease of application, pilot plant manufacturing and testing, and scaled-up to production batches.

Task 7–QPL Testing: This task will perform qualification testing on new formulations. Once a formulation has been finalized, qualification testing will be conducted on production batches of the material. MIL-S-81733 and AMS 3265 will be used for qualification test procedures.

ACCOMPLISHMENTS: This is a FY 1999 New Start.

TRANSITION: MIL-S-81733 will be revised and implemented throughout DoD to incorporate the new non-chromated sealant compound while meeting all the other specification requirements.

PROJECT SUMMARY

PROJECT TITLE & ID: Non-Polluting Composites for Remanufacturing and Repair for Military Applications; PP-1109

RESEARCH CATEGORY: 6.1 Basic Research

LEAD AGENCY: U.S. Army

LAB: Army Research Laboratory - Aberdeen Proving Grounds, MD

PRINCIPAL INVESTIGATOR: Dr. Bruce Fink

FY 1999 FUNDS: $997K

OBJECTIVE: The technical objective is to research, develop, and demonstrate a unique, affordable, environmentally friendly family of polymer-matrix composite (PMC) manufacturing and repair technologies for stand-alone repair of current, soon-to-be-fielded, and future DoD structures. Repair concepts and technologies will be demonstrated on three DoD-specific problems, including the design and implementation of a non-autoclave repair procedure for the oft-repaired helicopter rotor blades at Corpus Christi Army Depot (CCAD); the development, demonstration, and documentation of a repair-friendly processing method for the remanufacture of the Navy's fielding of the Advanced Enclosed Mast/Sensor System (AEMSS) including multi-functional material development; and the development of several advanced concepts for non-autoclave manufacture and repair of thin composite skins for aircraft and Army rotorcraft.

BENEFIT: This program will create technologies that enable out-of-autoclave processing as well as reduction of emissions from adhesive bonding operations. Used in tandem, these techniques can substantially reduce pollutants and waste in composite repair and remanufacturing. These technologies offer the additional benefit of significantly decreasing the need for recycling of scrap and waste materials by enabling materials to be used efficiently and the number of processing steps required for the manufacture of multi-functional PMC components (e.g., Crusader and AEMSS) to be reduced by up to 80 percent. In the AEMSS alone, cost savings in excess of $10M over the next 6-7 years are anticipated. This work will have significant 'buy-out' effects on the following requirements:

1. Hazardous materials substitution - substituting 100+ tons/yr. of thermoset adhesive on AEMSS through the co-injection process.
2. Minimization of hazardous emissions - vacuum-bag repair technologies to control and minimize hazardous effluents and alternatives to the use of adhesives in composite structure manufacturing.
3. Reduction of waste and environmentally friendly composites manufacturing - significant reduction in scrap (80 percent) in large-scale manufacturing for DoD applications such as AEMSS and Composite Armored Vehicle (CAV).

Specific benefits include the following:

a. Unlimited shelf life and elimination of associated waste.
b. Reduced-pollutant manufacturing and repair technologies enabled by new materials and curing methods.
c. Significant reduction in manufacturing waste and emissions for multi-functional composite structures.
d. Potential compliance fix for more-stringent processing-emissions standards.
e. Quantification of environmental benefits of nonautoclave, reduced-part-count, low-emission technologies.

TECHNICAL APPROACH AND RISKS: This program investigates a variety of novel composite processing and cure methods, including vacuum-assisted resin transfer molding (VARTM), the multi-resin co-injection process, electromagnetic PMC curing techniques, and novel portable radiation (ultraviolet and electron beam) cure techniques to solve pollution problems in composites remanufacturing and repair for military applications. A key to success is tight control over temperature during processing, reducing residual stresses and providing a consistent glass transition temperature (Tg) and consistent mechanical properties using recently invented composite manufacturing techniques and optimizing them for repair of complex DoD PMC structures.

ACCOMPLISHMENTS: Researchers continued the long-term testing program to investigate aging of incumbent thermally cured resin systems versus newly developed electron beam and induction formulations to aid in assessing potential environmental and cost savings. Additional tasks completed in FY 1998 include: a) quantified environmental benefits of e-beam and induction based repair; b) demonstrated accelerated curing of structural adhesives using induction heating; c) produced document for "Environmental and Cost-Savings Analysis"; d) demonstrated scheme for one and two-part free radical paste adhesives; and e) initiated testing and downselection for free radical adhesives.

TRANSITION: Systems of interest for the application of these novel manufacturing/repair methods and for specific demonstration of the technologies during this program include Army helicopter blade repair with the new Aviation and Missile Command and CCAD; the Navy's mast enclosure redesign, remanufacture, and repair procedure development with the Naval Surface Warfare Center; and Navy/Air Force aircraft skin non-autoclave manufacture and repair through Northrop Grumman and Science Research Lab.

PROJECT SUMMARY

PROJECT TITLE & ID: Genetic Enhancement of an Anti-Freeze Protein for Use as a Substitute for Ethylene Glycol for Aircraft Deicing; PP-1110

RESEARCH CATEGORY: 6.1 Basic Research

LEAD ORGANIZATION: U.S. Air Force

LAB: Air Force Research Laboratory - Tyndall AFB, FL

PRINCIPAL INVESTIGATOR: Dr. John Henry - Aspen Systems, Inc.

FY 1999 FUNDS: $206K

OBJECTIVE: Traditional anti-icing/deicing agents are either propylene or ethylene glycol. Glycols are effective in lowering the freezing point of water mixtures by the phenomenon of freezing point depression based solely on the molal concentration. The key environmental concerns with respect to use of ice control fluids are biological oxygen demand (BOD) loading and toxicity (human/mammalian and aquatic) resulting in extensive costs associated with the collection and cleanup associated with their use. For example, at Griffith AFB, NY, the use of glycols as a deicing fluid for aircraft has resulted in ground-water cleanup programs costing over $8.2M. Additionally, an Air Force policy has been issued banning future purchase of ethylene glycol.

The need to develop environmentally benign deicers is particularly urgent because of recently passed Environmental Protection Agency (EPA) regulations that are making the continued use of current deicers prohibitively expensive. These regulations require the construction of on-site collection and treatment facilities for the spent deicing chemicals. The immediate ramification of these regulations is that waste deicing fluid runoff will be classified as a non-storm water discharge which must have a low BOD, and hence this discharge requires an individual permit if it cannot be eliminated. In addition, it will be necessary to sample the storm water for deicing chemical content and develop a storm water pollution prevention plan.

In order to meet this challenge, this project proposes to produce novel deicing and anti-icing agents using naturally occurring antifreeze proteins, which have a very low BOD compared to the current agents. Initial research has indicated that *Dendriodes canadensis* protein found in insects produces a freezing point depression that is 300 to 500 times the predicted value based on its molal concentration due to non-colligative properties. This project proposes to genetically alter the *Dendriodes canadensis* antifreeze protein (AFP) gene in order to enhance the freezing point depression capabilities and therefore increase its usefulness and value as an aircraft deicing/anti-icing agent.

BENEFIT: The implementation of collection and treatment facilities translates to significant cost for the Air Force. Therefore the timely introduction of a nontoxic, low BOD deicer is particularly urgent. Aspen Systems deicing agent is based on a naturally occurring protein that will be nontoxic and have a low BOD.

When the cost of production of these proteins is calculated in conjunction with the lower management and litigation costs of their use, they will be a very economically viable and environmentally beneficial alternative to the current deicing agents. The production of an environmentally benign deicing agent by this program will be essential to the deicing of both civilian and military aircraft because it eliminates the high costs and associated danger of environmental pollution from this essential area of aircraft safety.

TECHNICAL APPROACH AND RISKS: Aspen Systems proposes to genetically alter the gene of its proprietary *Dendriodes canadensis* Antifreeze Protein in order to enhance the freezing point depression capabilities and therefore increase its usefulness and value as a wing deicing/anti-icing agent. The first year of this program (FY98) will be broken down into five tasks. These include: DNA Synthesis; Gene Mutation & Bacterial Cloning; DNA Sequencing; Yeast Cloning; and Initial Protein Expression.

Successful completion of the first year of this program will be the cloning, selection, and confirmation of the mutated antifreeze gene. We will also complete the initial expression of several of these mutated *Dendriodes canadensis* antifreeze proteins. The purification as well as the continued enhancement of the expression of the mutated proteins will occur within the second year of the program.

ACCOMPLISHMENTS: FY98 accomplishments include: The amino acid sequence analysis and binding domain comparisons of the *Dendroides canadensis* (D.can.) antifreeze protein with other published AFP sequences; the design, synthesis and confirmational sequencing of the mutagenesis DNA oligonucleotides to be used to mutate the D. can. AFP gene; the cloning of the D. can. AFP gene DNA in the pAlter II mutagenesis cloning vector; and the initial cloning of the mutant D. can. AFPs and the confirmation of their mutated sequences by DNA sequencing.

TRANSITION: All Services and the commercial airline industry will be apprised of initial results. Successful candidates may be further tested by Service programs.

PROJECT SUMMARY

PROJECT TITLE & ID: Environmentally Advantaged Substitutes for Ethylene Glycol for Aircraft Ice Control; PP-1111

RESEARCH CATEGORY: 6.2 Applied Research

LEAD ORGANIZATION: U.S. Air Force

LAB: Air Force Research Laboratory

PRINCIPAL INVESTIGATOR: Ms. Carolyn Westmark - Foster-Miller, Inc.

FY 1999 FUNDS: $614K

OBJECTIVE: The technical objective of this program is to develop a high performance, environmentally benign aircraft anti-icing fluid which can be safely released to the environment without capture, control, and post-treatment of the runoff. Specific objectives are to: (1) develop a molecular modeling approach which allows for prediction of non-Newtonian viscosity behavior of materials based on their chemical structure; (2) develop a non-toxic, non-Newtonian thickening agent with enhanced performance capabilities for anti-icing fluids, particularly extended holdover times; (3) select low environmental impact additives for performance enhancement; (4) demonstrate that the anti-icer formulations are compatible with military aircraft materials and weapons systems; (5) demonstrate the ability of the anti-icing formulations to prevent ice formation for extended periods of time in simulated adverse weather environments; (6) develop encapsulated enzyme additives which exhibit controlled release properties and actively degrade the anti-icer formulation at reduced temperatures; (7) predict the water quality impact of new anti-icer formulations at actual airfield sites using computer modeling and laboratory analysis of key environmental parameters; (8) determine any potential health/safety risks of anti-icing formulations; and (9) develop cost-effective anti-icing formulations by screening out excessively costly materials throughout the testing program. The most promising freezing point depressants from an earlier Air Force funded Small Business Innovation Research (SBIR) Phase I program will be used as a basis for anti-icer formulations.

BENEFIT: The project benefits include: (1) a drop-in, fully characterized, environmentally advantaged replacement for ethylene and propylene glycol based aircraft deicing materials; (2) elimination of the cost of capture/treatment of effluent from aircraft deicing processes; (3) reduction of material cost for aircraft deicing processes (since high efficiency fluids require less material usage); and (4) increased flight safety and mission readiness. Additionally, this project will provide a model for non-Newtonian viscosity prediction based on the chemical structure of compounds, a self-remediating anti-icing fluid formulation, and a model for predicting the impact of changes in ice control material formulation on runoff water quality at actual airfields.

TECHNICAL APPROACH AND RISKS: The Foster-Miller strategy to develop environmentally advantaged aircraft ice control materials involves three key elements: (1) substitution: identifying ice control material formulations which are inherently less damaging to the environment than currently used

materials; (2) source reduction: developing efficient, high performance fluids which require less material to accomplish the objective of protecting aircraft surfaces from ice accretion; and (3) "in-situ remediation": developing "self-remediating fluids" which degrade to less harmful products prior to entering the ecosystem by means of a triggerable reaction.

Foster-Miller is already pursuing the development of inherently environmentally advantaged freezing point depressants (FPDs) in a U.S. Air Force (Air Force Laboratory) sponsored SBIR program. This SERDP sponsored project focuses on the development of anti-icing fluids, which will incorporate the FPDs developed under the SBIR program. Anti-icing fluids offer source reduction benefits as compared to deicing fluids since less material is wasted on runoff and overspray and the material remains on the aircraft surfaces until takeoff to provide long lasting protection against icing, thus avoiding re-application of fluids. In addition, these anti-icing fluids offer advantages in terms of enhanced flight safety and mission readiness.

In this program, Foster-Miller will develop environmentally advantaged anti-icing fluids using all three elements of this strategy. This will be accomplished by: (1) identifying a wide range of candidate formulations, ranking them based on their predicted performance, environmental impact, and cost using computer model-aided screening, multi-tiered testing, and expert advice from aircraft deicing fluid manufacturers; and (2) developing high performance anti-icing fluids which require less material than current fluids to protect the aircraft from icing. The key to this approach is Foster-Miller's development of a high performance, environmentally benign thixotrope; and development of a gel-encapsulated, FPD-degrading enzyme system which will be incorporated into the anti-icing fluid and released on demand to initiate the degradation of the fluid into harmless byproducts.

During the first year of the program (FY98), Foster-Miller will identify non-Newtonian thixotropic agents and develop a model which predicts non-Newtonian viscosity of a compound based on its chemical structure. This model will be used to identify candidate thixotropic agents and synthesize new thixotropes with enhanced performance compared to currently available materials. Thixotropes will be added to freezing point depressant materials and their rheological behavior will be evaluated. The combination of thixotrope and freezing point depressant will be subjected to the first tier (screening) series of tests of performance, toxicity, materials compatibility, and cost. In addition, development of an enzyme which is active in degrading the FPD will be initiated in FY98.

ACCOMPLISHMENTS: Candidate FPDs identified with ultimate BODs less than propylene glycols. Screening tests completed on three commercially available. One meets most Tier 1 requirements with a 25 percent lower five-day BOD than propylene glycol. In the enzyme development part of the project, *Xanthobacter autotrophicus* shown to degrade PEG and PG at high concentrations (up to 25 percent) at room temperature, and grows on propylene glycol as sole carbon source and at reduced temperatures. Other psychrophiles under investigations. The encapsulation effort work resulted in evaluation of Dextran gel encapsulation, and demonstration of gel encapsulation of hemoglobin. The initial results indicate that the encapsulation concept is biodegradable, nontoxic, has good stability in water/FPD solutions, and is inexpensive.

TRANSITION: All Services and the commercial airline industry will be apprised of initial results. Successful candidates may be further tested by Service programs.

PROJECT SUMMARY

PROJECT TITLE & ID: Recycle and Reuse of Industrial Rags Using Liquid CO_2 and Surfactant Additives as a Cleaning Agent; PP-1112

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: Environmental Protection Agency

LAB: National Risk Management Research Laboratory

PRINCIPAL INVESTIGATOR: Mr. Charles H. Darvin

FY 1999 FUNDS: $307K

OBJECTIVE: The technical objectives of this proposal are to develop, demonstrate, and evaluate a liquid CO_2 (LCO_2) fabric cleaning technology for application to the cleaning of DoD generated hazardous cleaning rags. The most promising candidate technology to accomplish this objective is the use of liquid CO_2 (LCO_2) with surfactant additives. The economics of LCO_2/surfactants systems will be critically dependent on recovery and separation of surfactants, CO_2, and contaminants. LCO_2 has no associated environmental impacts and few safety concerns: it is non-hazardous, non-flammable, non-ozone-depleting, and non-toxic. Thus, there are none of the concerns which might be found with conventional cleaning technologies using organic solvents or aqueous solutions. Also, a system using liquid phase CO_2 is expected to be less destructive to fabrics. Finally, there is no pollution control process cost associated with achieving environmental compliance using the potential LCO_2 technology.

The initial focus of the program will be using CO_2 in the liquid phase, and not supercritical phase, unless research directions dictate a technical efficiency in the supercritical. Some studies outlined in the references on the use of CO_2 indicate that the use of CO_2 in the liquid phase will present a more efficient system for the cleaning of fabrics. A system operating in the liquid phase will present a more efficient system for the cleaning of fabrics. A system operating in the liquid phase is expected to be less destructive to fabrics and clothing as well as to attachments, such as buttons on work clothing.

BENEFIT: If contaminants contained on the rags can be removed successfully and collected, the rags can be recycled back to the operation and will eliminate rags as a source of hazardous waste pollution from DoD and related facilities.

A 1996 study, conducted for the Chief of Naval Operations, found that a minimum of $5M in rags are procured each year by the U.S. Navy for U.S. based facilities. This study did not include shipboard or foreign facilities. A major part of these rags is disposed of as hazardous waste at a disposal cost estimated to be in excess of $7M. This estimate results in an annual rag procurement and disposal cost for the U.S. Navy in excess of $12M. Rags generated on ships and at foreign facilities are required by many host countries to be transported back to the U.S. for disposal. It is reasonable to assume that an equal amount of rags are procured and disposed of by the remaining military Services. This would result in an additional

$24M in rag procurement and disposal cost for U.S. military services. The estimated cost savings in rag procurement and disposal for all U.S. military Services is therefore estimated at more that $360M over a 10-year period.

TECHNICAL APPROACH AND RISKS: The major objective during the FY98 Phase I portion of the program will be to conduct and complete research to design and synthesize LCO_2 compatible amphiphilic surfactants. The proposed surfactants will have a micelle-forming capability to emulsify lipophilic contaminants within a continuous LCO_2 phase. These surfactant systems must be applicable to a broad range of contaminants which will be defined by the potential users.

The chemical design philosophy of the candidate, micelle-forming surfactants to be synthesized during the Phase I effort is based upon results of surfactant research investigations recently published by Dr. J. DeSimone at the University of North Carolina. To date, two nonionic, amphiphilic copolymers have been synthesized. Accordingly, families of these amphiphilic surfactants will be tailored to meet the specific requirements necessary to emulsify and displace the contaminants typically found in industrial rags.

The use of CO_2 in the supercritical phase is a proven technology for certain applications such as precision metal cleaning and solid waste decontamination, or where the contaminant is primarily light organic compounds and non-particulate. However, LCO_2 has yet to be proven for fabric cleaning, or for military cleaning requirements which contain heavy molecular weight organic compounds, inorganic salts, metal oxides, proteins, and solid matter.

ACCOMPLISHMENTS: A survey was completed in March 1998 by the project team to establish the magnitude of the rag contamination and disposal problem. This assessment concluded that over 7 million pounds of rags are generated each year by the military services. The cost of rag waste disposal is estimated to be more than 24 million dollars. The project team also completed a preliminary rag pollutant identification and characterization assessment. This information is required to assist researchers in developing the correct surfactant formulation to address the cleaning requirements presented by DoD waste products. At the direction of the SERDP Science Advisory Board, a preliminary cost benefits analysis was completed by the project team. This analysis indicated that the 10 year cost savings can be as much as $360,000,000 in waste disposal savings and decreased purchases.

TRANSITION: The military Services will be apprised of initial results. Success may lead to cooperative Service programs.

PROJECT SUMMARY

PROJECT TITLE & ID: Sol-Gel Technology for Low VOC, Non-Chromated Adhesive & Sealant Applications; PP-1113

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Air Force

LAB: Air Force Research Laboratory - Wright Patterson Air Force Base, Dayton, OH

PRINCIPAL INVESTIGATOR: Mr. James Mazza

FY 1999 FUNDS: $950K

OBJECTIVE: The primary objective of this project is to develop and transition to the Department of Defense (DoD) and other organizations processes that eliminate the volatile organic compounds (VOCs), chromates, and strong acids typically found in the metal surface treatment and priming steps conducted prior to application of adhesives and/or sealants. Secondary objectives are the reduction of hazardous wastewater streams associated with current processes and improved performance compared to these processes.

This project will develop, evaluate, and field demonstrate nonchromated, zero VOC sol-gel processes for adhesive and sealant applications. The sol-gel processes developed will replace the current approaches that are high-VOC and/or chromate. They will also eliminate the current use of strong acids and reduce the waste streams associated with the existing processes.

BENEFIT: Development of new non-chromated, zero-VOC adhesive and sealant surface preparation and primer technologies will have a major impact on both cost and performance of military and commercial aircraft. Eliminating VOCs and chromates from these processes will result in considerable cost savings due to avoiding the need for hard controls and/or fines for non-compliance. These hard controls are mandated by Federal, state, and local agencies [the Environmental Protection Agency (EPA), the Occupational Safety and Health Administration (OSHA), California's Air Quality Management Districts (AQMD), etc.] through regulations such as the Clean Air and Water Acts, National Emission Standard for Hazardous Air Pollution (NESHAP), Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), and Resource Conservation and Recovery Act (RCRA) along with local EPA and AQMD rules. At Naval Depot (NADEP) North Island alone, the installation of VOC-control equipment for these processes is expected to cost $15M and the installation of chromate control equipment is expected to cost $2-3M, with operation costs of approximately $250K per piece of equipment annually. However, the majority of repairs at NADEP North Island are conducted on aircraft; thus, a mandate for hard controls will incur additional costs for removal of parts and increased aircraft downtime. Consideration of cost savings from other NADEPs, U.S. Air Force Air Logistics Centers (ALCs), Army depots, and commercial usage will multiply these cost avoidance figures many-fold.

Additionally, the new sol-gel processes are expected to provide increased bondline strength and/or durability for many applications; this will improve aircraft performance, decrease downtime and maintenance labor hours associated with reworking poor repairs, and enhance operational readiness.

TECHNICAL APPROACH AND RISKS: This project will build on recent work using sol-gel technology to deposit thin organic-inorganic coatings on metal surfaces to develop good adhesion between the metal and subsequently-applied polymers (primer, adhesive, or sealant) via covalent chemical bonding. A main feature of the effort is the extensive leveraging of previous, ongoing, and proposed research.

This project is divided into four tasks (three adhesive bonding and one sealant adhesion promoter/primer).

1. Find an environmentally friendly pretreatment/primer system that can be implemented in the near term by optimizing a sol-gel surface preparation that is compatible with experimental waterborne adhesive bond primers. This will be accomplished by sol chemistry optimization and by developing application procedures with emphasis on the surface activation drying/cure steps. Epoxy adhesives will be the primary focus, although polyamides may also be evaluated for titanium.
2. Develop a one-step process that combines the adhesive primer and sol-gel surface treatment into one consolidated interfacial layer. Findings regarding the important process variables identified in Task 1, such as surface activation for the various metal alloys, will be used to develop an application procedure. This approach will eliminate the need for a separate primer step.
3. Evaluate the sol/primer mixtures of Task 2 as traditional adhesive primers. The leading low-VOC primers, now on the verge of qualification, will be used without their chromate constituents.
4. Leverage the sol-gel work for adhesive bonding to develop adhesion promoters for sealant operations. The highest priority area will be replacing the high-VOC primers used with silicone sealants with a zero-VOC sol-gel alternative. A second priority will be to develop a universal adhesion promoter for polysulfide and polythioether sealants to promote adhesion between these sealants and various substrates as well as adhesion between the two sealant types.

ACCOMPLISHMENTS: Results of initial one-step (sol/primer mixture) testing using sol-gel chemistry with waterborne primer were promising on aluminum substrates. This formulation yielded good results on certain steel alloys during previous testing. These initial results show that good results can be obtained with an environmentally-friendly surface activation process.

TRANSITION: Further testing at NADEPs, Air Logistic Centers, and Army depots is anticipated after initial successes are achieved.

PROJECT SUMMARY

PROJECT TITLE & ID: Green Energetic Materials; PP-1115

RESEARCH CATEGORY: 6.1 Basic Research

LEAD ORGANIZATION: U.S. Navy

LAB: Naval Surface Warfare Center - Indian Head, MD

PRINCIPAL INVESTIGATOR: Marc Magdenic - Aspen Systems, Inc.

FY 1998 FUNDS: $2432K

OBJECTIVE: The objectives for the Green Energetic Materials Program are: 1) assess the current environmental issues associated with energetic materials and energetic material containing systems to identify major areas of concern for potential future SERDP R&D investments; 2) demonstrate innovative technologies that utilize liquid or super critical carbon dioxide, and enzymes for the synthesis of energetic materials; and 3) demonstrate the use of models and databases in a collective manner for use in designing and developing gun propellants that meet all environmental and performance requirements/goals.

TECHNICAL APPROACH AND RISKS: This project consists of the following four tasks:
1. Identify the environmental technology needs of military energetic materials community in the United States so that the SERDP Program Office can develop a strategic plan. The risk here is that the cost of the technology requirements identified will exceed the financial means of the SERDP.

2. Develop and scale-up enzyme and biomimetic catalyzed reactions to manufacture ingredients used in explosives and propellants that are currently manufactured in VOC solvents or using other environmentally undesirable materials and procedures. The four materials to be attempted include (1) a detection agent (taggant) called DMDNB required by international agreement on anti-terrorism for plastic (flexible) explosives; (2) making DNP, a plasticizer used in missile propellants, using the same procedure as DMDNB; making HNS, a energetic material used in warhead initiation systems and aircraft ejection seats; and (4) butanetriol Nitrate (BTTN), a widely used explosive ingredient. The risk here is that the yield from the enzymatic reactions will be too low to be used in an economical fashion in large-scale production.

3. Demonstrate the preparation of novel energetic polymeric thermoplastic elastomers (TPEs), nitramine oxidizers, and nitrate ester polymers and plasticizers using supercritical or liquid carbon dioxide (SC/L-CO_2) synthesis and processing technology. Further, SC/L-CO_2 processing technology will be employed for catalytic hydrogenations of polycylic caged alkyl substituted amines. The risk here is that existing procedures for each, proven in the laboratory, will not be amenable to being scaled-up to larger size.

4. A green gun propellants model-based formulation procedure will be assembled and provided to gun propellant formulation chemists and engineers. This formulation procedure will make it possible for the

formulator to reduce the number (and weight) of propellant samples needed to evaluate and optimize performance, vulnerability, chemical stability, safety, processing, environmental impact, and life-cycle cost. The consequence will be reduced waste and pollution during the entire life cycle of prospective gun propellants. The risk here is that the input information required to carry out the procedure requires information that the formulator cannot reasonable be expected to know or find.

ACCOMPLISHMENTS: Yields of DMDNB improved to 20% using horseradish peroxidase and soybean peroxidase. Nitrated glycidol (GN) in liquid carbon dioxide. Samples of GN and CDN are being characterized. Additionally, a successful workshop of energetics experts to assess the state-of-the-art within DoD and DOE and identify areas for future research and development. This workshop summarized into a technical report information on energetic materials as related to regulatory effects (now and projected); DoD and DOE end-user needs and concerns; and background information on important issues and needs. This report will help guide future SERDP and other DoD research and development efforts for green energetic material and processes.

TRANSITION: All Services and the commercial airline industry will be apprised of initial results. Successful candidates may be further tested by Service programs.

PROJECT SUMMARY

PROJECT TITLE & ID: Visual Cleaning Performance Indicators for Cleaning Verification; PP-1117

RESEARCH CATEGORY: 6.1 Basic Research

LEAD ORGANIZATION: Air Force

LAB: Air Force Research Laboratory, Columbus, OH

PRINCIPAL INVESTIGATOR: Dr. Bruce Monzyk - Battelle Columbus

FY 1999 FUNDS: $367K

OBJECTIVE: The visual cleaning performance indicators (VCPI) are a combination of intense dyes and coupling agents (CA) that selectively attach to target contaminants on surfaces cleaned in Department of Defense (DoD) and Department of Energy (DOE) operations. This innovative technology promises to provide a widely-applicable, real-time, low-cost, quantitative/qualitative cleaning process monitoring technique. The implementation of such a technique will reduce hazardous and non-hazardous waste and processing cost by (a) avoiding excessive as well as inadequate cleaning and by (b) enhancing implementation of environmentally friendly cleaning alternatives.

TECHNICAL APPROACH AND RISKS: The project consists of three tasks that will be carried out by Battelle in collaboration with Air Force Research Laboratory and Naval Surface Warfare Center-Carderock. This collaboration will ensure that the results from this project quickly lead to implementation in future efforts. In Task 1, the DoD partners will help identify target contaminants for large surface cleaning. Battelle will then select commercially-available CAs and dyes, that can attach to the target contaminants, using known science and with input from DoD partners on material compatibility. The Task 2 consists of feasibility testing of the VCPI concept. The DoD partners will prepare coupons for testing and Battelle will source the contaminant CAs and dyes. Battelle will then perform exploratory tests on bulk contaminants as well as soiled coupons to demonstrate selective labeling of target contaminants. The best VCPI combinations and delivery methods for cleaning operations will then be selected with inputs from the Advisory Panel and the DoD partners to assure that implementation of the technique proceeds rapidly after completion of this project. In the final task (No. 3), Battelle will clean the VCPI-treated soiled coupons to demonstrate a relationship between color intensity and residual contaminant level. The DoD partners on the other hand will perform application-specific cleaning to determine whether VCPI components are compatible with DoD cleaning operations and materials of construction.

ACCOMPLISHMENTS: This is a FY 1999 New Start.

TRANSITION: At the conclusion of this project, Battelle plans to work with DoD/DOE organizations to field test the technique, specifically for aircraft cleaning (OC-ALC), application of adhesives and painting of shipboard surfaces (NAVSEA),and DOE (Pantex) application to critical cleaning for weapons manufacture and demilitarization.

PROJECT SUMMARY

PROJECT TITLE & ID: Supercritical Fluid Spray Application Process for Adhesives and Primers; PP-1118

RESEARCH CATEGORY: 6.1 Basic Research

LEAD ORGANIZATION: Air Force

LAB: Air Force Research Laboratory - Dayton, OH

PRINCIPAL INVESTIGATOR: Dr. Marc Donohue - Johns Hopkins University

FY 1999 FUNDS: $318K

OBJECTIVE: The objective of this project is to develop or identify low/no-VOC (volatile organic compound), non-structural adhesives to substitute for the current high-VOC, non-structural adhesives used in military applications. It is estimated that 8.5 billion pounds of synthetic polymer adhesives are used annually, of which approximately 55 percent are VOCs. While the total DoD usage is not known, it is estimated that approximately 173,000 pounds of VOCs are released annually by Air Force aircraft operations alone. VOCs commonly used in applying adhesives include aromatics (e.g., toluene), ketones (e.g., acetone, methyl ethyl ketone), and others (e.g., methanol, chloroform) which negatively impact worker health and safety, adversely affect environmental standards, are ozone depleting, and result in increased hazardous material management costs including permitting and installation of sophisticated emission control equipment.

TECHNICAL APPROACH AND RISKS: Conceptually, the UNICARB process is straightforward in that a concentrated solution of polymeric material (in this case the adhesive and adhesive primers), and other additives are mixed in situ with high-pressure (in the range of 1000 psi to 2000 psi) carbon dioxide and then sprayed. In practice, the process is complicated in that one is mixing an incompressible, highly viscous material (polymeric material and solvents) with a highly compressible fluid of very low viscosity (supercritical carbon dioxide). The solvents are mixtures of fast and slow evaporating VOCs which are chosen specifically for their ability to dissolve the polymeric material, reduce viscosity, and aid in atomization and droplet coalescence on the substrate. In the supercritical spray process, supercritical carbon dioxide replaces that fraction of the organic solvent that is needed to give the viscosity reduction necessary for spray atomization. This is also the solvent that is the primary contributor to the high VOC emissions.

For a polymeric material to be adapted to the UNICARB process, the phase behavior of that particular polymeric material (the adhesive in this case) with carbon dioxide has to be known. Mixtures of high-pressure carbon dioxide with the adhesive concentrate must exist as a single phase at elevated pressures for the UNICARB[7] process to work. To-date, little is known of the phase behavior of polymer-solvent-carbon dioxide mixtures, and determining the underlying thermodynamic and rheological behavior is an arduous trial and error process. Additionally, precipitation of solids in solution has been encountered and

needs to be avoided when using this process.

This project will adapt the UNICARB spray application process to adhesives in two ways: 1) a continuous process for use in a manufacturing setting and 2) a portable hand held batch process for use in small jobs or repair scenarios. Each of these processes requires its own unique set of phase diagrams given that the portable device operates in dynamic conditions, that is, the materials and pressures of the system are changing with time, whereas the continuous spray operation operates in a steady state mode, that is, the system pressure and material compositions remain constant with time. Therefore, for each adhesive adapted to the UNICARB process, two different types of phase diagrams will need to be generated.

The goals of this 4-year project are to adapt six non-structural adhesives to both a continuous and portable UNICARB process. Given this objective, in combination with the above technical challenges, the following approach will be taken to achieve the goals and deliverables of this project:

1) The polymeric material and solvent constituents of the six adhesives will be evaluated for their compatibility to the process. 2) The identity and proportion of the various high and low volatile solvent constituents comprising the present adhesive mixture will be determined. 3) Once the phase behavior is determined the configuration of the batch and continuous process will be established and tested. 4) Based on the above tests, formulation of the supercritical carbon dioxide-solvent-polymer mixture will be further investigated for optimization of performance properties and minimization of environmental impacts. 5) After determination of the optimal adhesive formulations, both processes will be field tested on various applications at venues to be determined by the respective military collaborators for this project. 6) For each adhesive that is reformulated and adapted to the UNICARB process, a concurrent effort will be made to develop the underlying thermodynamic and rheological behavior.

While no technical difficulties are anticipated, there is potential for; a) the solvent/polymer system not to be compatible with the phase behavior requirements particular to the UNICARB process; b) adhesive performance and environmental compliance not to meet military specifications; and, c) the portable hand-held spray device not being adaptable to a two-phase UNICARB process.

ACCOMPLISHMENTS: This is a FY 1999 New Start.

TRANSITION: Two key customers, Tank Automotive & Armaments Command and Aviation & Missile Command, have expressed interest in participating in the program. Additionally, the Prinicipal Investigator plans to work with adhesive manufacturers and equipment companies.

PROJECT SUMMARY

PROJECT TITLE & ID: Critical Factors for the Transition from Chromate to Chromate Free Corrosion Protection; PP-1119

RESEARCH CATEGORY: 6.1 Basic Research

LEAD ORGANIZATION: U.S. Army

LAB: Army Research Laboratory - Aberdeen Proving Grounds, MD

PRINCIPAL INVESTIGATOR: Dr. Rudolph Buchheit - Ohio State University

FY 1999 FUNDS: \$470K

OBJECTIVE: The overall objective of this research program is to acquire a fundamental understanding of the chemical and physical processes and mechanisms of corrosion protection by chromate-based coatings applied to metal surfaces with a specific focus on corrosion protection of aluminum alloys. Specific objectives of this program are to: (1) define a set of phenomenological and fundamental rules that describe the role of microstructural heterogeneity in chromate conversion coating formation and breakdown; (2) define the relationship between chromate conversion coating structure and chemistry, and coating properties for coatings applied under non-ideal conditions such as those that exist during coating applications in manufacturing and military maintenance depot environments; (3) determine the extent to which application method, coating age, and alloy substrate chemistry affect the self-healing nature of chromate coatings; and (4) develop rapid, quantitative, and predictive tests to assess properties and performance of chromate conversion coatings. It is a further objective to work interactively with the Air Force Office of Scientific Research sponsored Multi University Research Initiative, which also examines fundamental aspects of corrosion inhibition by chromates.

TECHNICAL APPROACH AND RISKS: This program comprises a four year fundamental research effort conducted jointly by Ohio State University, the Air Force Research Laboratory, and the Army Research Laboratories. Informal technical collaborations are planned with the Air Force Corrosion Program Office, the Aluminum Company of America - Alcoa Technical Center, and the Naval Air Defense Center. Research activities are focused in three topical areas.

The first research activity focuses on the role of microstructural heterogeneity in the alloy substrate on chromate conversion coating formation and breakdown. The approach for adding new insight to the fundamental understanding of corrosion inhibition of al alloys is to examine and characterize the interaction of important Al-based intermetallic compounds with key coating process chemistries and service environments. Two general experimental approaches will be used in this regard. First, intermetallic compounds will be synthesized in bulk form for characterization by conventional electrochemical and surface analytical techniques. Second, small length scale probes will be used to interrogate coating formation and breakdown processes at relevant microstructural length scales (0.5 to 10 μm).

The second research activity focuses on the relationship between coating structure, chemistry with coating properties and performance when the coating suffers from non-idealities such as advanced age, exposure to conditions that subsequently impair coating corrosion resistance mechanisms, (such as exposure to ultraviolet light), or less-than-ideal application methods. These effects will be studied by examining coatings returned from the field after service and by simulated exposure testing under controlled conditions.

The third research activity focuses on development of rapid, quantitative, and predictive tests to measure corrosion protection. The approach is based on the use of electrochemical methods, like electrochemical impedance spectroscopy and electrochemical noise to quantitatively detect the onset of chromate coating breakdown. these quantitative assessments will form the basis for rapid, predictive methods for determining coating performance and life.

ACCOMPLISHMENTS: This is a FY 1999 New Start.

TRANSITION: All Services and DoD partners will be apprised of initial results from this fundamental research and will be used to aid in modifying procedures and specifications for corrosion protection by coatings.

PROJECT SUMMARY

PROJECT TITLE & ID: Mechanisms of Military Coatings Degradation; PP-1133

RESEARCH CATEGORY: 6.1 Basic Research

LEAD ORGANIZATION: U.S. Army

LAB: Army Research Laboratory - Aberdeen Proving Ground, MD

PRINCIPAL INVESTIGATOR: Dr. Steven McKnight

FY 1999 FUNDS: $600K

OBJECTIVE: Military coating systems are usually repainted for the following reasons: loss of appearance (aesthetics, camouflage, cleanliness); chipping, peeling, debonding of the coating; and corrosion of the substrate. The primary technical objective of this project is to identify, model, and predict degradation mechanisms that lead to military coating system failures and force depaint/paint operations to occur. An overall deliverable of the proposed effort would be pollution prevention via intelligent reduction of the paint/repaint frequency. The project will develop models of coating degradation and provide a scientific basis to develop new durable coating formulations that will help to achieve this goal. The research findings will be transitioned through appropriate vehicles to the Army, Navy, Air Force, and Marine Corps. The outcome of this program will have a positive impact on both pollution prevention and cost avoidance to the Department of Defense.

TECHNICAL APPROACH AND RISKS: This program will pursue a multi-disciplinary highly leveraged approach to study the degradation mechanisms leading to paint/repaint operations. The complexity of the problem demands complementary studies to fully understand the degradation mechanisms. In this work, we have selected to study the mechanisms of military coatings degradation used on aircraft (NAVY), combat ground vehicles (ARMY, MARINES), and support equipment (NAVY, ARMY, and MARINES). Efforts will focus on primer/topcoat systems that are being fielded to comply with environmental legislation and regulations. Both accelerated tests as well as static and dynamic field conditioning to assess coatings degradation in military systems and environments will be investigated. Most prior coatings degradation work has focused on commercial systems and has attempted to relate accelerated lab tests to actual service conditions. The response of any coating system to the environment is complicated and depends on resin type, pigment-resin, primer-topcoat, and primer-substrate interactions. Each element must be addressed to fully understand the degradation mechanisms of the coating system as a whole. Nevertheless, useful information has been obtained to both screen coatings for durability and provide some indication of useful service life.

This program will quantify and model the degradation modes that lead to these failures. A thorough and detailed materials characterization of the coatings will be critical to provide baseline properties and subsequent changes upon weathering. The characterization will focus on bulk coating properties, surface

and interface analysis, and corrosion behavior. The results will be closely linked to understand synergistic interactions between properties. Degradation of topcoat appearance and protective ability due to exposure to ultraviolet radiation and moisture will be quantified and modeled. Also, the effect of topcoat degradation on corrosion resistance and primer-substrate adhesion will be determined quantitatively and related to service life. Accelerated testing methodologies will be developed and validated that will facilitate more rapid fielding of future environmentally compliant coating systems with greater confidence and understanding. The end result of this project will be an understanding of the mechanisms that explain the degradation of organic coating systems when exposed to military type environments. These mechanisms will be modeled and included in a statistical method for accurately predicting the performance of coating systems. Furthermore, we will publish an extensive database on the World Wide Web as well as formal reports that document results from accelerated aging, static weathering, and dynamic weathering of the new water-reducible coatings systems that are targeted for insertion in the near future.

ACCOMPLISHMENTS: This is a FY 1999 New Start.

TRANSITION: The results and models will be transitioned by promoting their use, as bases for defining performance criteria, and in the contracts issued during the acquisition (or rebuild) process. Additionally, the models can be incorporated into materials specifications and/or manuals as criteria for qualification or use. Finally, standardization and industry acceptance of such models would be pursued (FED STD, ASTM, SSPC, NACE, etc.).

PROJECT SUMMARY

PROJECT TITLE & ID: Development of Innovative Nondestruction Evaluation (NDE) Technologies for the Inspection of Cracking and Corrosion under Coatings; PP-1134

RESEARCH CATEGORY: 6.1 Basic Research

LEAD ORGANIZATION: U.S. Navy

LAB: Naval Surface Warfare Center - Carderock, MD

PRINCIPAL INVESTIGATOR: Michelle Novack

FY 1999 FUNDS: $595K

OBJECTIVE: The objective of this program is to develop and evaluate 3 technologies for their viability as nondestruction evaluation (NDE) tools for the detection of cracks and corrosion under surface coatings in aircraft and ground vehicle applications. They have been developed in the private sector under either private or SBIR program funding and have shown promise for meeting the technical and sometimes unique logistical needs of DoD aircraft and ground vehicle applications. The technologies include: 1) Ultrasound Imaging, 2) Thermal Imaging, and 3) Near-Field Microwave Imaging. These technologies were proposed for investigation based on their potential to inspect areas rather than points (translating into efficient levels of inspection scan rates), portability to the job site, overall projected economy to implement, and relative technology maturity.

TECHNICAL APPROACH AND RISKS: Conventionally, the problems of corrosion (chemical degradation) and fatigue cracking (mechanical degradation) have been addressed through the application of surface coatings and NDE inspections (e.g., eddy current or magnetic particle methods). These practices remain a significant portion of the maintenance budget for each system and play a major factor in overall system readiness especially since the conventional NDE methods require the removal of surface coatings in order to conduct interrogations of the metallic substrate. According to an recent estimate, the ability to detect and repair corrosion areas prior to severe degradation will reduce operational maintenance cost by 25% and will improve operational readiness.

In order to properly detect corrosion and diagnose the severity and the impact that it might have on the structure, advanced NDE methods are required as well as corrosion models that correlate the NDE signal with severity of corrosion. The Naval Surface Warfare Center and Naval Air Warfare Center leveraging with prior Navy SBIR programs will investigate three NDE techniques for the detection of corrosion, namely - Ultrasound Imaging, Thermal Imaging, and Near Field Microwave Imaging. Two of the techniques, Ultrasound and Microwave imaging, are believed to be effective in detecting cracks under coatings and will be investigated for that purpose, as well. In parallel to NDE techniques development, models will be developed to correlate with the output signature of these various techniques. Electrochemical Impedance Spectroscopy (EIS) will be used to validate the measurements. Finally, a "round robin" test will be performed to determine the most effective NDE technique for detecting

corrosion.

ACCOMPLISHMENTS: This is a FY 1999 New Start.

TRANSITION: All Navy Ship Systems experimentation stations will be apprised of the results from this program for actual in-service field trials. Additionally, some technologies may prove to be mature enough for transition to commercial development will be pursued.

PROJECT SUMMARY

PROJECT TITLE & ID: Primerless RTV Silicone Sealants/Adhesives; PP-1135

RESEARCH CATEGORY: 6.1 Basic Research

LEAD ORGANIZATION: U.S. Army

LAB: TACOM-ARDEC - Picatinny Arsenal, NJ

PRINCIPAL INVESTIGATOR: Dean Martinelli

FY 1999 FUNDS: $731K

OBJECTIVE: Room temperature vulcanizing (RTV) silicones, developed in the late 1940's, have played an important role in the design and superior performance of weapon systems (airplanes, missiles, electronics, ammunition, vehicles and nuclear weapons) developed by the DoD and DOE. A unique combination of properties has made them the material- of- choice for designers wanting to improve and increase weapon performance. RTV silicones are used as adhesives, sealants, coatings, heat insulators and encapsulating materials. For RTV silicones to achieve a high level of consistent adhesion to various substrates, a saline primer is applied prior to silicone application. These primers contain 90-98% volatile organic compound (VOC) solvents, which evaporate into the air. The objective of this project is the development, evaluation and transition of a primerless self- bonding low temperature curable addition cured silicone, which eliminates the use of high VOC primers without compromising durability, compatibility, thermal resistance and long term stability.

TECHNICAL APPROACH AND RISKS: The project will be conducted in four phases. In the first phase, which poses the least risk, reformulation efforts will utilize "off the shelf" adhesion-promoting technology already developed by General Electric - Corporate Research and Development (GE-CRD). In phase I, current addition cured silicones will be modified with a bifunctional adhesion promoter compound. In phase II, a less inhibiting adhesion promoter, based on structures defined by molecular modeling will be utilized in an attempt to develop room temperature curing systems. This phase will pose moderate risk as new synthesis and new formulations will be required. Laboratory adhesion evaluations will be used to establish "go/no go" criteria for technology development in phase II.

To expand adhesion capability to a variety of substrate materials, including plastics, novel adhesion promoting concepts will be evaluated in phase III. In this phase, multiple adhesion promoting functionalities will be evaluated in a rational fashion using guidance from molecular modeling predictions. Phase IV, will demonstrate the use of a new primerless silicone formulation. Current addition cured silicones with the use of a primer were used successfully to adhere sapphire windows as part of the laser ignition program.

ACCOMPLISHMENTS: This is a FY 1999 New Start.

TRANSITION: The transition of this technology will occur through revision of military specifications (MIL-A-46106, etc.) and by modification of current data packages with engineering change proposals (ECP).

PROJECT SUMMARY

PROJECT TITLE & ID: Nondestructive Testing of Corrosion under Coatings; PP-1137

RESEARCH CATEGORY: 6.1 Basic Research

LEAD ORGANIZATION: U.S. Navy

LAB: Naval Air Warfare Center - Patuxent River, MD

PRINCIPAL INVESTIGATOR: Joanne McLaughlin - Northrup Grumman

FY 1999 FUNDS: $268K

OBJECTIVE: Surface corrosion on aluminum aircraft skins and around joints and fasteners is often the precursor to buried corrosion. Aircraft paints are routinely removed to reveal the presence of corrosion on the surface of metal structures and the aircraft is subsequently repainted. Aircraft painting and repainting operations result in significant emissions of volatile organics, organic and inorganic hazardous air pollutants, and hazardous waste. The objective of this project is to develop nondestructive inspection techniques to detect the presence of corrosion under an organic film in order to reduce the amount of painting and depainting that is performed. More specifically, the inspection and measurement techniques can be used to: 1) target and map specific areas that require maintenance due to corrosion, thus eliminating the need to completely strip and reapply the exterior coatings, 2) verify the condition of the coating allowing for a migration from schedule-based to condition-based maintenance, and 3) verify the condition of the primer and surface preparation after the topcoat has been removed to eliminate a portion of the rework that now routinely occurs.

TECHNICAL APPROACH AND RISKS: This project will develop: 1) a spectral NDE technique employing an optical reflectance probe in the near/mid IR region combined with Directional Hemispherical Reflectance (DHR) and FTIR integrated detector; 2) Wide-area spectral imaging (WASI) using spectral filters and high-resolution focal plane cameras to allow rapid initial assessment of sub-paint corrosion; and 3) a Scanning Kelvin Probe (SKP) electrochemical method employing a calibrated capacitance probe to indirectly measure corrosion potential across a surface. Challenges to be overcome include probe positioning and electrical noise.

The project will consist of five tasks over four years: 1) baseline measurements of unexposed coatings and typical corrosion products to build up a database of standards; 2) evaluation of aged aircraft components; 3) optimization of measuring systems at varying levels of corrosion and their modification for field use; 4) prototype verification (in conjunction with NAWCAD); and 5) preparation of a transition plan for cost-effective applications.

ACCOMPLISHMENTS: This is a FY 1999 New Start.

TRANSITION: Weapon systems will be identified that can use the spectral imaging and electrochemical measurement technologies to assess the condition of underlying substrates relative to corrosion without coatings removal.

PROJECT SUMMARY

PROJECT TITLE & ID: Cleaning Verification Techniques Based on Infrared Optical Methods; PP-1138

RESEARCH CATEGORY: 6.1 Basic Research

LEAD ORGANIZATION: U.S. Department of Energy

LAB: Sandia National Laboratory - Albuquerque, NM

PRINCIPAL INVESTIGATOR: David Otteson

FY 1999 FUNDS: $500K

OBJECTIVE: The objective of this project is to develop a real-time method to provide both qualitative and quantitative assessments of surface cleanliness for a wide variety of military cleaning applications. The introduction of new environmentally acceptable solvents for traditional chlorinated hydrocarbon materials has produced major uncertainties in standard cleaning procedures. As a result, many applications over utilize solvents to ensure component cleanliness and the success of any subsequent processing operations (such as coating or bonding). This, in turn, leads to the additional usage, handling and disposal of hazardous materials, while also wasting personnel operating time. This project will develop two prototype infrared-optical instruments with complementary capabilities for use at DoD sites that will reduce the use, emission and handling of hazardous materials in cleaning operations, and will also be applicable to DOE and commercial sector needs.

TECHNICAL APPROACH AND RISKS: Currently, the detection of surface contamination on reflective surfaces is most convenient and rapidly done by the Fourier Transform Infrared (FTIR) reflectance method which provides both quantitative and qualitative information on surface coatings. However, it is greatly limited in its ultimate sensitivity to surface contaminants by the nature of its optical design.

Sandia National Laboratory (DOE) in partnership with Naval Facilities Engineering Service Center (NFESC), propose to develop two prototype instruments with complementary capabilities for cleaning verification. In each case, surface contamination will be detected via alteration of the grazing-incidence infrared reflectance of the surface. Specifically, the project will: 1) develop a prototype on-line widely tunable infrared laser based instrument with high speed surface-imaging capability but with limitations on the number of detectable organic contaminants; and 2) optimize an FTIR based instrument with high sensitivity for organic species on a variety of surfaces, but with limitations on speed and surface coverage for real-time analysis of surface contaminants at very low level of concentrations. The proposed instruments will differ in the nature of the information they provide. The first will produce images that directly indicate the spatial extent and location of contamination. The second will provide a spectrally-resolved measurement of the surface reflectance at a single point.

ACCOMPLISHMENTS: This is a FY 1999 New Start.

TRANSITION: Transition to both research and development organizations and DoD end users will be integrated over the life of the project through field testing at DoD facilities, communicating the results to DoD and DOE users, and aggressive pursuit of commercialization.

PROJECT SUMMARY

PROJECT TITLE & ID: Non-Structural Adhesives Requiring No VOCs; PP-1139

RESEARCH CATEGORY: 6.1 Basic Research

LEAD ORGANIZATION: U.S. Air Force

LAB: Air Force Research Laboratory - Dayton, OH

PRINCIPAL INVESTIGATOR: Dr. Fred Albert - Montana Biotech Corporation

FY 1999 FUNDS: $241K

OBJECTIVE: Polymeric adhesives are used in a variety of joining applications in the military and civilian sectors. Adhesives currently in use generally contain epoxy-polyamides, polyurethane, polysulfides, or alpha-cyanoacrylates. These adhesives require toxic volatile organic components (VOCs) to polymerize, and therefore pose a significant health hazard. The VOCs commonly utilized include toluene, acetone, methanol, ketone, or xylene. Based on Toxic Release Inventory information (1996), it is estimated that 1.6 million pounds of VOCs are released annually through military use of solvent based adhesives. Personnel at manufacturing and repair facilities are at particular risk since the toxic effects of VOCs are evident at concentrations less than parts per million.

The objective of this proposal is to develop innovative, compliant adhesive polymers that have no requirement for volatile organic compounds. The source of these novel polymers will be microorganisms isolated from high temperature waters. Developed compounds will be environmentally safe, thermostable, and water tolerant. The adhesives will meet the minimum requirements of physical property performance and materials compatibility as generally required by MMM-A-121, A-A-1936, MMM-A-139, MMM-A-1058, MMM-A-1617 and MIL-A-5540.

TECHNICAL APPROACH AND RISKS: The overall technical approach of this project is to identify natural adhesive compounds produced by microorganisms isolated from high temperature aqueous environments. 500 microorganisms from the Montana Biotech in-house collection will be grown in mini-fermenters and the cells separated from the culture broth. The culture broth containing extracellular polymers will be subdivided into three crude fractions: whole culture broth, exopolysaccharide, and protein components. Each crude fraction will be tested for tensile adhesive properties and compared to adhesives currently in use by the Army and Air Force. For example, the Army currently uses Permatex PR1 (Loctite) and Scotch-Grip 1300L (3M) that meets Mil Spec standard MMM-A-121. Polymers in crude fractions with comparable adhesive properties will be purified to homogeneity. The pure adhesive will be analyzed by time of flight secondary ion mass spectrometry (TOF-SIMS) and attenuated total reflectance fourier transform infrared spectrometry (ATR-FTIR). TOF-SIMS will generate information regarding the structure and composition of the adhesive compound and its association with various surfaces. ATR-FTIR data will include the kinetics of adhesion and bond stability on hydrophilic and hydrophobic surfaces. The physical performance of the pure adhesive polymer will be determined using mil spec standards for tensile

and shear properties. If the native microorganism proves to be problematic in terms of adhesive production, and the adhesive is a protein product, the gene encoding the adhesive compound will be identified and cloned into a more industrially applicable microorganism.

The technical aspects and difficulties of the project approach are divided into the following four aspects: 1) Selection and culturing of adhesive producing microorganisms, 2) Physical performance, 3) Chemical analysis, and 4) Small scale production.

ACCOMPLISHMENTS: This is a FY 1999 New Start.

TRANSITION: The non-structural adhesives will be tested as necessary to qualify for Army, Navy, Air Force, and DOE applications as well as for use in the private sector.

APPENDIX E
FY 2000 Statements Of Need

Cleanup

Compliance

Conservation

Pollution Prevention

STATEMENT OF NEED FOR FY 2000 SERDP CLEANUP NEW START

IN-SITU TREATMENT TECHNOLOGIES FOR AMMONIUM PERCHLORATE CONTAMINATED GROUND WATER

OBJECTIVE: The primary objective of this statement of need is to develop abiotic and biotic approaches for the cost effective, in-situ treatment of groundwater contaminated with ammonium perchlorate at DoD, DOE, and defense contractor facilities. Research and development activities at the laboratory-, bench-, and small field-scale will be considered. Work conducted in response to this statement of need does not necessarily have to culminate in a field demonstration. The product of this research will include development of first principles understanding of applicable abiotic and biotic in-situ treatment approaches under realistic environmental conditions.

BACKGROUND: Ammonium perchlorate is used as an oxidizer component in solid propellant (fuel) for rockets, missiles, and fireworks. Approximately 90% of ammonium perchlorate produced in the U.S. is used as a solid rocket fuel oxidizer. The handling of perchlorates by the manufacturers and the rocket propellant industry has led to widespread contamination of surface and groundwaters. The high solubility of ammonium perchlorate coupled with its chemical stability in water leads to expansive plumes. These same chemical properties make ammonium perchlorate contamination difficult to remediate by conventional physical-chemical water treatment methods.

Recent advances in the analytical detection capability for low concentrations of perchlorate, from 400 to 4 parts per billion (ppb), have led to the discovery of the chemical at various manufacturing sites and some drinking water supply wells. Although perchlorate is a suspected endocrine disrupter, interfering with iodine uptake in the thyroid, it is not yet regulated by the Safe Drinking Water Act (SDWA). The state of California, however, has established a provisional action level of 18 ug/L (18 ppb) for drinking water, and the EPA national guideline has set limits of between 4 and 18 ppb to avoid health risks. Under the Safe Drinking Water Act, as amended in 1996, the EPA was required to develop a list of contaminants, known as the Contaminant Candidate List (CCL), that are known or anticipated to occur in public water systems and that may require regulation under SDWA (section 1412(b)(1)). As a result of public comment on a draft of the CCL published on October 6, 1997 (62 FR 52193), perchlorate was added to the final CCL that was published on March 2, 1998 (63 FR 10274).

The development of abiotic or biotic in-situ methods for treating large volumes of groundwater contaminated with perchlorate is necessary to adequately address this national concern. Robust methods capable of treating large concentration ranges of perchlorate as well as the ability to perform in the presence of co-contaminants are needed.

STATEMENT OF NEED FOR FY 2000 SERDP CLEANUP NEW START

BIOAVAILABILITY AND LONG-TERM STABILITY ISSUES ASSOCIATED WITH METALS IN SOILS

OBJECTIVE: The primary emphasis of this statement of need (SON) is to develop a better fundamental understanding concerning the bioavailability and long-term stability issues associated with metals in soils. This SON seeks a greater knowledge of the science regarding the behavior/chemical state of metals in soils and improved measurement techniques to assess bioavailbility so as to address the technology gaps that adversely influence risk assessments and remediation of metals contaminated soils.

BACKGROUND: There are nearly 17,000 sites on DoD installations potentially requiring environmental cleanup. The challenges facing those involved in cleanup include distinguishing those sites that pose significant environmental risks from those that pose little risk, prioritizing contaminated sites by the degree of risk posed, quantifying the risks at each site, and developing appropriate remedial actions and cleanup goals where appropriate.

During the last 30 years, the science of environmental risk assessment and understanding of the fundamentals of the fate of metals in soils and the environment have greatly improved. Many areas of research on metals have provided information to build this fuller understanding, including metals in fertilizers, pesticides, manures, limestones, and biosolids used in agriculture; paint; automotive exhausts; smelter and other stack emissions and slags; mine wastes; fly ash; flue gas desulfurization residues; dredged materials; and geological (geogenic) sources of soil metal enrichment. Although each metal in each source could have unique properties in each soil and each plant, general principles have been established for the fate and potential effects of metals in different sources applied to soils. Knowledge of the risks from soil metals has come from toxicological studies, epidemiological studies, agricultural and soil chemical studies, and studies of livestock and wildlife.

STATEMENT OF NEED FOR FY 2000 SERDP CLEANUP NEW START

ESTABLISH BETTER UNDERSTANDING OF AEROBIC AND ANAEROBIC TRANSFORMATION OF cis-DICHLORETHENE AND VINYL CHLORIDE

OBJECTIVE: This statement of need seeks innovative laboratory- and bench-scale research approaches that will yield a better fundamental understanding of potential aerobic and anaerobic transformation mechanisms for cis-Dichloroethene (cis-DCE) and vinyl chloride (VC). In addition, it should lead to a better understanding of what site specific factors control these transformation processes in the subsurface environment and how to cost effectively identify them as an aid to design site specific remediation approaches.

BACKGROUND: A large body of evidence has accrued concerning the aerobic and anaerobic metabolism of tetrachloroethene (PCE) and trichloroethene (TCE). Under aerobic conditions, PCE is considered non-degradable, while TCE can be cometabolized to mainly CO_2 and other non-toxic products by various oxygenases, such as methane monooxygenase and toluene dioxygenase. Under anaerobic conditions, PCE and TCE can be reductively dechlorinated to cis-DCE, either as a cometabolic process involving reduced transition metal cofactors or as an anaerobic respiratory process in which PCE or TCE serve as electron acceptors for energy conservation and growth. Several bacteria that carry out the transformation of PCE and TCE to cis-DCE have been isolated. Such bacteria are diverse and widely distributed, and reductive dechlorination to cis-DCE is nearly assured at an anaerobic contaminated site if sufficient electron donor is present and other environmental conditions, such as pH, are appropriate.

Less is known about the metabolism of cis-DCE and VC. cis-DCE can be reductively dechlorinated to VC, which in turn can be reduced to ethylene. Only one bacterial strain that can carry out these reactions has been isolated thus far, but there is evidence for the existence of several other, as yet uncharacterized, organisms capable of ethylene production. Recently, the oxidation of cis-DCE to CO_2 under manganese dioxide-reducing conditions and VC oxidation under Fe (III)-reducing conditions have been documented. However, nothing is known about the responsible organisms. Under aerobic conditions, cis-DCE can be cometabolically oxidized by oxygenases, but no evidence has been obtained for cis-DCE utilization as a carbon and energy source. A single pure culture has been described which aerobically oxidizes VC to CO_2.

STATEMENT OF NEED FOR FY 2000 SERDP COMPLIANCE NEW START

DISTRIBUTION AND ENVIRONMENTAL FATE OF ENERGETICS ON DOD MUNITIONS TEST AND TRAINING RANGES

OBJECTIVE: The objective of this statement of need (SON) is to develop the techniques and knowledge that will allow the DoD to effectively assess the potential for environmental impact by residual energetic material at test and training ranges. Specific issues to address include assessment of the potential for, distribution of, and environment transport of such residues as a result of the activities and management practices that occur on military ranges. The energetic materials include, but are not limited to, military explosive compounds such as trinitrotoluene (TNT), pentaerythriol tetranitrate (PETN), cyclotrimethylenetrinitramine (RDX), and cyclotetramethylenetetranitramine (HMX). The energetic material itself, its combustion products, and any breakdown products, are all of concern.

BACKGROUND: The purpose of the proposed work is to focus research attention on developing techniques to allow assessment of the potential for environmental impact by those residual energetic materials that might be expected at military ranges as a result of the use of munitions. The research conducted under guidance of this SON is intended to contribute to the DoD's capacity to: 1) understand range environmental issues; 2) improve management of these critical resources; 3) assure the long-term viability of these key assets; 4) facilitate compliance with current and proposed regulations; 5) meet future requirements for advanced weapon systems development; and 6) ensure the effective incorporation of these systems into new combat strategies needed to meet the defense requirements of the 21st Century. It supports the 1996 Defense Science Board (DSB) Report and Environmental Security Plan for test and training range sustainment. The SON can also contribute to the research, development, test, and evaluation responsibility of the DoD Operational and Environmental Executive Steering Committee for Munitions (OEESCM) for munitions-related technologies.

Testing activities, in the most general sense, are the final steps in the weapons systems' development and acquisition process. At this point, Defense leadership makes critical decisions to acquire a particular combat system or system component, or to redesign or reject all or part of a system. New systems enter the inventory through various levels of test activities to verify new concepts and military performance. In addition to new systems development, testing activities frequently involve a variety of performance evaluation activities related to lot acceptance verification and life cycle testing of inventory items. The other major military range usage involves training activities. Test and training activities can differ markedly in that testing is often intermittent and can involve unique materials, or materials that have not been characterized in detail and which that may ultimately fail to become part of an inventory system. Such materials may result in residual energetic materials that could pose a potential for impact to the environment. In contrast, training activities involve the same munitions used in combat, and those munitions are used in larger quantities than in testing. In addition, specifically designed training munitions (often inert) are also employed in training. In summary, a broad range of munitions are used on military test and training ranges, and residual energetic materials from that use suggest there is a potential for environmental impact.

STATEMENT OF NEED FOR FY 2000 SERDP
COMPLIANCE NEW START

THE FATE AND IMPACT OF COPPER AND ZINC IN HARBORS AND ESTUARIES

OBJECTIVE: The objective of this statement of need is to advance the current scientific knowledge of the fate and impact of copper (Cu) and zinc (Zn) from DoD sources in harbors and estuaries in order to develop a scientific basis for future approaches to copper and zinc regulations. Efforts to further study the fate and impact of copper and zinc in harbors and estuaries should focus on: (1) the development of standardized analytical methods for sampling and the analysis of copper and zinc activities; (2) in-situ physical and biological processes that may affect copper and zinc speciation/activity and bioavailability; and (3) the translation of toxicological effects on individual organisms to populations and communities.

BACKGROUND: Copper and zinc are two of the most ubiquitous contaminants found in many industrial and non-point source effluent, including discharges from DoD facilities, ships, and small craft into the marine environment and sediments disrupted during dredging operations. DoD sources of copper include storm waters, point sources, hull coatings, and discharges from DoD ships and facilities. Studies have shown that copper and zinc are highly toxic to some marine organisms. Copper and zinc discharges often exceed existing water quality criteria (WQC) or standards in the effluent and copper often exceeds WQC in the receiving systems. Regulatory compliance is often challenging because of the many copper sources, both natural and introduced, and the adoption of very conservative water quality standards.

Present WQC for these metals are based on concentrations of total dissolved copper. In contrast, a large body of scientific data indicates that it is the concentration of the "free" or aqueous species (i.e., Cu(II)aq) which correlates most closely with the toxicity of marine organisms. EPA- mandated WQC for copper effluents are at or very close to the ambient or "normal" concentrations of copper in many estuaries. In order to assess the effects of copper on aquatic organisms, sensitive analytical methods are necessary to determine the concentrations of the various species of copper. At present there are no standard acceptable methods to directly determine the concentration of the "free" or aqueous species (i.e., Cu(II)aq) in water and sediment columns. Methods presently available include anodic stripping voltammetry, cathodic stripping voltammetry, graphite furnace atomic absorption spectroscopy (GFAAS), and copper ion selective electrode. The GFAAS is the only EPA approved method but is not sufficiently sensitive to measure copper directly in any but the most contaminated estuarine waters. For zinc, similar sensitive analytical techniques are not available and need to be developed and verified.

STATEMENT OF NEED FOR FY 2000 SERDP CONSERVATION NEW START

RIPARIAN ZONE REHABILITATION TO RESTORE TERESTRIAL AND AQUATIC ECOSYSTEM FUNCTIONS

OBJECTIVE: The objective of this statement of need (SON) is to solicit proposals for development of data, analysis, tools, and models necessary to maximize the benefits from riparian zone rehabilitation technologies. The focus is on technologies designed for the dual purpose of sustaining of military lands and mitigating aquatic and terrestrial ecological impacts associated with military land use activities. Proposals responding to this SON should address some or all of the following objectives:

- Determine the impacts military activities upon aquatic ecosystems and water quality.
- Determine what benefits maybe derived from riparian zone and stream corridor rehabilitation and management programs on military lands as they affect aquatic ecosystem structure and function.
- Determine if riparian zones and stream corridors can be intensively managed to achieve multiple ecosystem protection and restoration goals. Specifically, determine if restoration and management of riparian zones provide a substantial benefit to terrestrial systems/habitats while also maintaining aquatic species.
- Identify the principal physical, chemical, and ecological requirements (in a management and technology sense) that need to be addressed to manage riparian zones and stream corridors such that functions of both terrestrial and aquatic ecosystems are sustained. These requirements may include, but are not limited to: controlling biogeochemical cycling; building habitat features; and understanding plant dynamics, geomorphology, hydrology and sediment transport.

BACKGROUND: Increasingly, data are showing that terrestrial and aquatic ecosystems are linked and that their structures and functions overlap to the degree that human impacts on the one can be detrimental to both. In a watershed context, this is very evident in the case of soil disturbance with subsequent erosion, sedimentation, and deleterious impacts on aquatic life in the watershed drainage systems. Recently, the role of stream corridors and riparian zones in maintaining habitats for both terrestrial and aquatic species has been highlighted. For example, a number of federal agencies have collaborated to issue the handbook on Restoration of Stream Corridors as a guide for natural resource agencies. Put simply, stream corridors are identified as important features of the landscape for both aquatic and terrestrial ecosystems. Water quality may be largely influenced by riparian zones (e.g. nutrient removal, sediment removal, wetland maintenance, and carbon storage) and such zones also provide habitat for a wide array of terrestrial species.

STATEMENT OF NEED FOR FY 2000 SERDP CONSERVATION NEW START

NATURAL RESOURCES MANAGEMENT CONTROL OF NON-INDIGENOUS INVASIVE SPECIES

OBJECTIVE: The objective of this statement of need (SON) is to solicit proposals for developing new or improving existing methods for the early identification, monitoring, and management/control that would lead to reduction and possible elimination of non-indigenous invasive plant and animal species on Department of Defense (DoD) installations. Proposals responding to this SON should address some or all of the following objectives: (1) Develop methods to inventory the spatial extent and, where applicable, the densities of established populations of non-indigenous species on military bases; (2) Develop methods to estimate the likelihood of non-indigenous species expansion into and/or invasion of, new habitats/areas on military bases; (3) Improve existing and/or develop new and more effective management/control technologies against established and expanding populations of non-native introduced species while effectively protecting native species and their habitats.

BACKGROUND: Many non-indigenous invasive species have devastating impacts on ecosystems of all sizes and types. With few natural enemies, many non-indigenous (sometimes noxious and/or exotic) species are able to occupy suitable ecological niches, often enabling them to spread quickly, infesting large areas. In the process, they devastate local plant and animal communities by replacing native vegetation, by predation on native species, and by altering and degrading habitats of indigenous flora and fauna.

Non-indigenous invasive plants and animals present a serious problem to the health and diversity of plant and animal communities by altering and/or replacing native flora and fauna. Invasive aquatic plants significantly affect the use of inland water bodies for sport fishing, recreational boating and waterborne commerce. These plants also contribute to the loss of wetlands by replacing native wetlands species. On cultivated and rangelands, terrestrial invasive plants crowd out desirable forage, exacerbate soil erosion, and make these lands generally unsuitable for agriculture and grazing. Once established, it is all but impossible to completely eradicate noxious weeds. The spread of invasive plant species alone is the second leading cause of habitat destruction in the U.S., overtaking 4,600 acres of land per day. Loss of habitat is the principal cause for species extinction. The cost associated with the permanent loss of native plant communities and habitats for numerous native animal species is incalculable.

Rapid identification and assessment techniques must be developed in order to contain, manage/control and, if possible, eradicate newly introduced exotics, especially those with highly invasive characteristics. Scientifically based information to identify the invasive characteristics of species and the susceptibility of ecosystems will provide a basis for avoiding invasion of aggressive or noxious species. In addition, survey, monitoring, and assessment technologies are needed to determine the extent and rate of spread on DoD and other lands. Once populations of invasive species and their areas of infestation are identified, techniques have to be developed for the efficient management and control of those populations. Because of the nature of invasive species, there is a compelling need to share analytical tools, standards, data, and other management resources and information among all potentially affected land managers.

STATEMENT OF NEED FOR FY 2000 SERDP
CONSERVATION NEW START -
SERDP Ecosystem Management Project (SEMP)

ECOLOGICAL DISTURBANCE IN THE CONTEXT OF MILITARY LANDSCAPES

OBJECTIVE: The overall intent of this statement of need (SON) is to develop the knowledge required to implement adaptive ecosystem management approaches for military lands and waters, as well as other federal facility lands and waters. Proposed efforts should address one or more of the following objectives:

- Identify the historical range of variation in types, spatial extent, intensities and frequencies of natural disturbances across the landscape associated with specific ecological and/or land use conditions.
- Describe how current DoD activities within the ecosystem compare to past disturbance regimes, in terms of affecting specific ecological and/or land use conditions.
- Determine whether there are thresholds in spatial extent, intensity or frequency above and/or below which the natural system cannot sustain identified ecological and/or land use disturbances.

BACKGROUND: SERDP sponsored a workshop on Management Scale Ecosystem Research (June 1997) which identified a number of opportunities and needs for improving scientific foundations for ecosystem management. This workshop led to the development of the SERDP Ecosystem Management Project (SEMP). The goal of SEMP is to conduct research to support DoD installations in accomplishing ecosystem management objectives, while maintaining land and water resources to accomplish military training and testing missions. The objectives of SEMP will focus on research to (i) determine indicators of environmental change, (ii) to identify critical thresholds (either natural or anthropogenic) of ecological change, and (iii) examine types, intensities and frequencies of natural and anthropogenic disturbances that can be sustained by an ecosystem. This SON is part of a series of SONs designed to implement the SERDP SEMP initiative. The focus here is on the role of military activities within the long-term dynamics of the ecological landscape. The continual environmental monitoring of Fort Benning has been termed the SEMP Ecosystem Characterization and Monitoring Initiative (ECMI). The goal of the ECMI is to design, develop and demonstrate an ecosystem monitoring protocol in support of SEMP objectives. The protocol will be demonstrated at Fort Benning.

It is understood that certain types, intensities and frequencies of disturbance are desirable and play important roles in the functioning of ecosystems. From a management point of view, it is important to understand how human activities compare to natural disturbances in effect and extent and frequency, and it is important to respond in a way that promotes or detracts from desired conditions through time and space. Improved understanding leads to more appropriate ecosystem or management response; for example, it may be determined that disturbances in certain locations or at certain times require aggressive response whereas disturbances in other locations or at other times are acceptable without intervention. It is likely that the effect of a given disturbance only can be evaluated within the context of other ecological conditions and disturbance across the landscape. Such perspective should assist DoD and other federal agency land managers in compliance with Federal laws and regulations and with efforts to maintain sustainable conditions for military and non-military land uses.

STATEMENT OF NEED FOR FY 2000 SERDP POLLUTION PREVENTION NEW START

ALTERNATIVE TECHNOLOGIES TO HARD (WET) CHROME ELECTROPLATING

OBJECTIVE: The objective of this statement of need is to develop environmentally friendly replacement technology for current wet hard chrome electroplating for defense applications. The focus of this program is on non-line-of-sight applications and other applications where current High Velocity Oxy-Fuel (HVOF) technology cannot be used to replace electroplating. Such configurations include angles, crevices, and inside of holes or tubular shapes. Innovative application techniques and alternative materials will be considered. The proposed technologies or innovative enhancements must:

- Achieve surface builds, hardness, and smoothness that are comparable to hard chrome electroplating in non-line-of-sight such as closed and open cylinders up to 5 feet long and as narrow as 1 inch in diameter and/ or angles, crevices, and inside of holes or tubular shapes;
- Possess fewer inherent environmental and worker safety risks than wet hard chromium electroplating;
- Include pre- and post-processing requirements in environmental and worker safety risk assessments and cost analyses;
- Provide cost effective life cycle performance (including component rework and repair requirements) that is comparable or better than wet electroplated hard chrome; and
- Provide the same or improved level of performance as current electroplating processes.

BACKGROUND: Metallic chromium is the preferred surface material for many applications where wear resistance, dimensional consistency and/or smoothness are required on substrates which are chosen for other key material properties. By far, the most common method of applying chromium is via wet immersion electroplating. Electroplating of chromium, as currently practiced, involves the use of a heated, agitated, corrosive solution of a heavy metal in its water-soluble form. A cornucopia of add-on devices and treatment processes are used to keep this inherently dirty, polluting and unsafe operation in compliance with ever tightening environmental and worker safety regulations.

STATEMENT OF NEED FOR FY 2000 SERDP
POLLUTION PREVENTION NEW START (FEDERAL LABORATORIES ONLY)

ENVIRONMENTALLY INNOVATIVE TECHNOLOGIES FOR SPECIALTY COATINGS APPLICATIONS/REMOVAL AND REPAIR

OBJECTIVE: The objective of this statement of need is to develop environmentally benign application, removal and repair processes for specialty coatings that meet unique requirements of DoD weapon systems. These specialty coatings contribute greatly to the military mission and often are enabling technologies. Proposed work can focus on any of the following special use coatings: rain and dust erosion control on aircraft leading edges and radomes; fuel tank corrosion control; air/sea/ground-based antennae and support structures signature reduction; thermal barriers; and composites. The proposed specialty coating(s) application/removal and repair technology must be addressed from a systems level and exhibit potential for lower life cycle environmental impact than the current specialty coatings processes.

BACKGROUND: The implementation of National Emissions Standards for Hazardous Air Pollutant (NESHAP) requirements specific to the use and removal of general aerospace coatings has fostered significant research and development for environmentally benign general aerospace coatings over the past few years. Very little work has been done to improve specialty coatings application and removal processes because they have been exempted from regulation and are not presently limited to a set amount of volatile organic compounds (VOC) and/or hazardous air pollutants (HAP) per unit volume. However, their contribution to atmospheric releases is significant. In addition, the total VOC and HAP emissions at any individual facility or location are often locally controlled and are of major concern. Specialty coatings contribute to these total emissions and must be addressed to insure compliance with minimal mission impact.

Removal of speciality coatings has been primarily by sanding or through the use of high VOC solvents. Due to the hazardous material content of the coatings and therefore the associated sand residues or dissolved residues, these residues are considered to be hazardous material. These add to the large and increasingly expensive hazardous material wastes to be stored and eventually disposed of by the depots and aircraft logistic centers. Coating removal technologies, such as waterjet, flashjet and laser removal, are promising and possess a number of advantages. However, these often have disadvantages involving such characteristics such as high investment costs, extensive training, additional systems testing, development of revised maintenance documentation. They also have not been developed for use with the various small geometries associated with antennae or with base materials, such as composites or other mixed materials as may be found on radomes or new composite structures.

APPENDIX F
LIST OF ACRONYMS

A/C	Aircraft
AAP	Army Ammunition Plant
ACA	Air Compliance Advisor
ADN	Ammonium Dinitramide
ADPA	American Defense Preparedness Association
AEC	Army Environmental Center
AEMSS	Advanced Enclosed Mast/Sensor System
AFB	Air Force Base
AFCEE	Air Force Center for Environmental Excellence
AFCESA	Air Force Civil Engineering Support Activity
AFM	Atomic Force Microscopy
AFOSR	Air Force Office of Scientific Research
AFRL	Air Force Research Laboratory
AFRL/EQ	Air Force Research Laboratory/Environmental Quality
AFRL/MLQ	Air Force Research Laboratory/Materials Laboratory
AH	Attack Helicopter
AHPC	Army High-Performance Computing
AICUZ	Air-Installation Compatible Use Zone
Al	Aluminum
ALC	Air Logistics Center
AMS	Aerospace Materials Specifications
ANL	Argonne National Laboratory
ANM	Animal Noise Monitor
ANSI	American National Standards Institute
AOP	Advanced Oxidation Process
AQMD	Air Quality Management Districts
ARA	Applied Research Associates
ARDEC	(U.S. Army) Armaments Research, Development & Engineering Center
AREP	Alternative Refrigerant Evaluation Program
ARL	Army Research Laboratory
ARM	Atmospheric Radiation Measurement
ARPA	Advanced Research Projects Agency
ARS	Agriculture Research Service
ARSAP	Atmospheric Remote Sensing and Assessment Program
ASAN	Assessment System for Aircraft Noise
ASPA	Advanced Solid Propellant Armament
ASTE	Advanced Strategic and Tactical Expendables
ASTM	American Society for Testing and Materials
ATD	Advanced Technology Demonstration

ATEDS	Advanced Technology Expendables and Dispenser System
ATLAS	Advanced Testing Line for Actinide Separations
ATOC	Acoustic Thermometry of Ocean Climate
ATOFMS	Aerosol Time of Flight Mass Spectrometer
ATR	Automated Target Recognition
ATR-FTIR	Attenuated Total Reflectance Fourier Transform Infrared Spectrometry
ATRP	Automatic Target Recognition Processor
ATTACC	Army Training and Testing Area Carrying Capacity
BAA	Broad Agency Announcement
BDC	Background Data Center
BDK	Batch Design Kit
BLM	Bureau of Land Management
BOD	Biological Oxygen Demand
BOQ	Bachelor Officers Quarters
BRAC	Base Realignment and Closure
BSAA	Boric-Sulfuric Acid Anodizing
BTEX	Benzene, Toluene, Ethylbenzene, and Xylene
C3P2	Cleanup, Compliance, Conservation, Pollution Prevention
CA	Coupling Agent
CAA	Chromic Acid Anodizing
CAA	Clean Air Act
CAAA	Clean Air Act Amendments
CAME	Clean Agile Manufacturing of Energetics
CARB	California Air Resources Board
CARC	Chemical Agent Resistant Coating
CART	Cloud and Radiation Testbed
CATS	Controlled Archeological Test Site
CAV	Composite Armored Vehicle
CBC	Construction Battalion Center
CCAC	Close Combat Armament Center
CCAD	Corpus Christi Army Depot
CCC	Chromate Conversion Coatings
CCD	Charge Coupled Devices
Cd	Cadmium
CDI	Capacitive Deionization
CE	Civil Engineering
CEMS	Continuous Emissions Monitoring System
CER	Center for Environmental Research
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (called Superfund)
CERL	U.S. Army Construction Engineering Research Laboratory
CFC	Chlorofluorocarbon

CFD	Computational Fluid Dynamics
CHPPM	Center for Health Promotion and Preventive Medicine
CHSSI	Common High-Performance Scalable Software Initiative
CIA	Central Intelligence Agency
CL-20	Hexanthrohexaazaisowurtzitane
CMS	Cylindrical Magnetron Sputtering
CNO	Chief of Naval Operations
COTS	Commercial-off-the-Shelf
CPAT	Corrosion Prevention Advisory Teams
CPC	Corrosion Prevention Compound
CPT	Cone Penetrometer
Cr	Chromium/Chromates
CRADA	Cooperative Research and Development Agreement
CRREL	U.S. Army Cold Region Research and Engineering Laboratory
CTC	Control Technology Center
CTIO	Coatings Technology Integration Office
Cu	Copper
CUSP	Commander, Undersea Surveillance Pacific
CW	Continuous Wave
CWA	Clean Water Act
DAF	DNA Amplification Fingerprint
DALM	Diazoluminomelanin
DARPA	Defense Advanced Research Projects Agency
DC	Direct Current
DCA	Dynamic Contact Angle Analyzer
DCA	Dichloroethane
DCE	Dichloroethylene
DECIM	Defense Environmental Corporate Information Management
DEM/VAL	Demonstration/Validation
DENREC	Delaware Department of Natural Resources and Environmental Control
DERA	Defense Environmental Restoration Account
DESCIM	Defense Environmental Security Corporate Information Management
DFA	Difluoroamino
DFSS	Dedicated Feedstock Supply Systems
DHR	Directional Hemispherical Reflectance
DMA	Differential Mobility Analyzers
DMMF	Developmental Manufacturing and Modification Facility
DMMP	Dimethylmethylphosphonate
DNA	Defense Nuclear Agency
DNAPL	Dense Non-Aqueous Phase Liquid
DNB	Dinitrobenzene
DNL	Dry Low NO_x
DoD	Department of Defense

DOE	Department of Energy
DOI	Department of the Interior
DPG	Dugway Proving Ground
DRE	Destruction and Removal Efficiency
DUECC	Defense Utility Energy Coordinating Council
DUSD(ES)	Deputy Under Secretary of Defense for Environmental Security
EA	Environmental Assessment
EAE	Environmentally Acceptable Endpoint
EAM	Effective Area Model
ECIP	Energy Conservation Investment Program
ECMI	Ecosystem Characterization and Monitoring Initiative
ECP	Engineering Change Proposal
ECU	Environmental Control Unit
EDYS	Ecological Dynamics Simulation
EIS	Electrochemical Impedance Spectroscopy
EIS	Environmental Impact Statement
EM	Electromagnetic
EM	Environmental Management
EMAA	Encapsulated Micron Aerosol Agents
EMAP	Environmental Monitoring and Assessment Program
EO	Electro-Optic
EO	Executive Order
EOS	Earth Observing System
EPA	Environmental Protection Agency
EPCRA	Emergency Planning and Community Right to Know Act
EPRI	Electric Power Research Institute
EQT	Environmental Quality Technology Program
ERAP	Environmental Risk Assessment Program
ERDEC	U.S. Army Edgewood Research, Development and Engineering Center
ERPM	Emission Reduction Planning Model
ES	Enviroene (EPA Information Umbrella)
ESA	Endangered Species Act
ESMB	Explosive Standoff Minefield Breecher
ESTCP	Environmental Security Technology Certification Program
EXCEL	Experimental Chloride Extraction Line
FAA	Federal Aviation Administration
FDS	Fixed Distributed Systems
FEDS	Federal Energy Decision Screening Model
FEMP	Federal Energy Management Program
FFCA	Federal Facilities Compliance Act
FIC	Fluoroiodocarbon
FID	Free-Induction Decay

FORS	Fiber Optic Raman Sensor
FOX	Fluoroalkoxymethyl-3methyl-Oxetane
FPD	Freezing Point Depressant
FTS	Fourier Transform Spectrometer
FUDS	Formerly Used Defense Sites
FWPPCA	Federal Water Pollution Prevention and Control Act
GAC	Granular Activated Carbon
GC	Gas Chromatography
GCDIS	Global Change Distributed Information System
GC/FID	Gas Chromatography/Free Induction Decay
GC/MS	Gas Chromatography/Mass Spectrometry
GEM	Navy Green Energetics Manufacturing Program
GIMI	Global Imagery Monitor of the Ionosphere
GIS	Geographic Information System
GISS	Goddard Institute for Space Studies
GMS	Groundwater Modeling System
GO	Genetic Optimization
GOCO	Government-Owned/Contractor-Operated
GOES	Geostationary Operational Environmental Satellites
GPR	Ground-Penetrating Radar
GPS	Global Positioning System
GRASS-PRISM	Geographic Resource Analysis Support System - Planning and Resource Integration Stewardship Model
GRFL	Groundwater Remediation Field Laboratory
GSE	Ground Support Equipment
GUI	Graphical User Interface
GV	Grassland Value Function
GWP	Global Warming Potential
HAP	Hazardous Air Pollutant
HAZMAT	Hazardous Materials
HAZMIN	Hazardous Waste Minimization
HBNQ	High-Bulk-Density Nitroguanidine
HCFC	Hydrochlorofluorocarbon
HF	Hydrogen Fluoride
HFC	Hydrofluorocarbon
HMT	High Mesa Technologies
HMX	Octahydro-1,3,5,7-Tetranitro 1,3,5,7-Tetrazocine
HOPS	Heuristic Optimized Processing Systems
HPLC	High Performance Liquid Chromatography
HSRC	Hazardous Substance Research Center
HSSDS	Hazardous Solvent Substitution Data System
HUD	Department of Housing and Urban Development

HVLP	High Volume Low Pressure
HVTS	High Velocity Thermal Spray
HW	Hazardous Wastes
HWRC	Hazardous Waste Research Center
IBEAM	Installation Baseline Energy Analysis Model
ICA	Incremental Cost Analysis
ICAO	International Civil Aviation Organization
ICUZ	Installation Compatible Use Zone
IDIF	Integrated Diffuser, Injector, Flameholder
IDLAMS	Integrated Dynamic Landscape Analysis and Modeling System
IHPTET	Integrated High Performance Turbine Engine Technology
INEL	Idaho National Engineering Laboratory
IPD	Integrated Product Development
IPM	Integrated Pest Management
IPPD	Integrated Product/Process Development
IPT	Integrated Product Team
IR	Infra-red
IRIS	Integrated Risk Information System
IRP	Installation Restoration Program
ISCT	In-Situ Chemical Treatment
IUSS	Integrated Undersea Surveillance System
IVD	Ion Vapor Deposition
IWTP	Industrial Waste Treatment Plants
JASPA	Joint Acquisition Sustainment Pollution Prevention
JATO	Jet Assisted Take Off
JDEP	Joint Depot Environmental Panel
JEMP	Joint Engineers Management Panel
JETC	Jet Engine Test Cell
JGAPP	Joint Group for Acquisition Pollution Prevention
JHU/APL	John Hopkins University Applied Physics Laboratory
JPG	Jefferson Proving Ground
JPL	Jet Propulsion Laboratory
KBB	Karner Blue Butterfly
LAAP	Louisiana Army Ammunition Plant
LAMS	Laser Ablation Mass Spectroscopy
LANL	Los Alamos National Laboratory
LCA	Life Cycle Assessment
LCAAP	Lake City Army Ammunition Plant
LCAD	Life Cycle Assessment and Design
LCED	Life Cycle Engineering and Design

LCI	Life Cycle Inventory
LCO_2	Liquid CO_2
LCTA	Land Condition Trend Analysis
LFA SURTASS	Low Frequency Active Surveillance Towed Array Sonar Systems
LHM	Lead-Based Paint Hazard Management System
LIBS	Laser-Induced Breakdown Spectroscopy
LIF	Laser-Induced Fluorescence
LIN	Liquid Nitrogen
LIS	Laser Ignition System
LLNL	Lawrence Livermore National Laboratory
LMS	Lead Hazard Mitigation Management System
LNAPL	Light Non-Aqueous Phase Liquid
LOVA	Low Vulnerability Ammunition
LRS&T	Long Range Science and Technology Program
M&S	Modeling and Simulation
MADOM	Magnetic and Acoustic Detection of Mines
MAJCOM	Major Commands
MALDI	Matrix Assisted Laser Desorption Ionization
MAOP	Mobile Meteorological Observation Platform
MARPOL	International Maritime Organizations Marine Pollution Convention
MARS	Mobile Analytical Reconnaissance System
MAS	Millimeter-Wave Atmospheric Sounder
MB/MS	Molecular Beam/Mass Spectrometric
MBT	Membrane BioTreatment
MCB	Marine Corp Base
MCFC	Molten Carbonate
MCRA	Material/Chemical Risk Assessment
MDA-E	McDonnell-Douglas Aerospace-East
MECL	Methylene Chloride
MEK	Methyl Ethyl Ketone
MFR	Monthly Financial Reporting
MIBK	Methyl Isobutyl
MIC	Metastable Interstitial Composites
MIDAS	Munitions Items Disposal Action System
MIPR	Military Interagency Purchase Request
MIT	Massachusetts Institute of Technology
MM	Modifier Molecules
MMATS	Marine Mammal Acoustic Tracking System
MMMS	Mobile Meteorological Measurement System
MMPA	Marine Mammals Protection Act
MMRP	Marine Mammal Research Program
Mn	Manganese
MODIS	Moderate-Resolution Imaging Spectroradiometer

MOI	Multiorifice Impactors
MPC	Mobile Power Center
MR/H	Mine Reconnaissance/Hunter
MRTFB	Major Range and Test Facility Base
MT3D	Modular Transport in 3D
MTADS	Multi-Sensor Towed Array Detector System
MTR	Military Training Routes
MTV	Magnesium-Teflon-Viton
MUDSS	Mobile Underwater Debris Survey System
MWCO	Molecular Weight Cutoff
MWOs	Modification Work Orders
NAAQS	National Ambient Air Quality Standards
NADEP	Naval Depots
NAGPRA	Native American Grave Protection and Repatriation Act
NAPL	Non-Aqueous Phase Liquid
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
NAVSEA	Naval Sea Systems Command
NAX	Natural Attenuation of Explosives
NBS	National Biological Survey
NC	Nitrocellulose
NCAR	National Center for Atmospheric Research
NCBC	Navy Construction Battalion Center
NCIBRD	National Center for Integrated Bioremediation Research and Development
NCMS	National Center for Manufacturing Sciences
NDCEE	National Defense Center for Environmental Excellence
NDE	Nondestruction Evaluation
NDFT	Non-local Density Functional Theory
NDI	Nondestructive Inspection
NDI	Non-Developmental Item
NEETC	National Environmental Education and Training Center
NEPA	National Environmental Policy Act
NERL	National Exposure Research Laboratory
NESHAP	National Emission Standard for Hazardous Air Pollution
NETTS	National Environmental Technology Test Sites
NFESC	Naval Facilities Engineering Services Center
NG	Nitroguanidine
NGB	National Guard Bureau
NGP	Next Generation Fire Suppression Technology Program
NHPA	National Historic Preservation Act
Ni	Nickel
NIST	National Institute of Standards and Technology
NMERI	New Mexico Engineering Research Institute

NMFS	National Marine Fisheries Service
NMP	N-Methyl-Pyrolidone
NMR	Nuclear Magnetic Resonance
NN	Neural Network
NOAA	National Oceanic and Atmospheric Administration
NOV	Notice of Violation
NOx	Nitrogen Oxide
NPDES	National Pollutant Discharge Elimination System
NPS	National Park Service
NQ	Nitroguanidine
NRaD	Naval Research and Development Center
NRC	National Research Council
NRHP	National Register of Historic Places
NRL	Naval Research Laboratory
NRMRL	National Risk Management Research Laboratory
NSPS	New Source Performance Standards
NSWC	Naval Surface Warfare Center
NSWC-IHD	Naval Surface Warfare Center - Indian Head Division
NTIS	National Technical Information Service
NTP	Non-Thermal Plasma
NUFT3D	Non-Isothermal Unsaturated/Saturated F&T in 3D
OB/OD	Open Burning/Open Detonation
OC-ALC	Oklahoma City Air Logistics Center
ODC	Ozone Depleting Chemicals
ODOBi	High Explosive Capacity Facility for Open Burning/Open Detonation Testing
ODP	Ozone Depleting Potential
ODS	Ozone Depleting Substances
ODUSD(ES)	Office of the Deputy Under Secretary of Defense for Environmental Security
OEM	Original Equipment Manufacturer
OEW	Ordnance Explosive Wastes
ONI	Office of Naval Intelligence
ONR	Office of Naval Research
OPC	Optical Particle Counters
OPNAV	Naval Operations, Headquarters Staff (Pentagon)
OPNAVINST	Naval Operations Instruction
OS3D	Operator Splitting in 3D
OSHA	Occupational Safety and Health Administration
OTD	Office of Technology Development
OWS	Oil/Water Separators
PAA	Phosphoric Acid Anodize
PAFC	Phosphoric Acid Fuel Cells
PAH	Polycyclic Aromatic Hydrocarbon

PAS	Photoelectric Aerosol Sampler
Pb	Lead
PBPK	Physiologically-Based Pharmacokinetic
PCA	Tetrachloroethane
PCB	Polychlorinated Biphenyls
PCE	Perchloroethylene (tetrachloroethylene)
PCR	Polymerase Chain Reaction
PDM	Programmed Depot Maintenance
PED	Photoacoustic Elemental Device
PEO	Program Executive Officer
PEO/FAS	Program Executive Officer for Field Artillery Systems
PEP	Propellants, Explosives, Pyrotechnics
PG	Propylene Glycol
PI	Principal Investigator
PLIBS	Portable Laser-Induced Breakdown Spectroscopy
PM	Particulate Matter
PM	Program Manager
PMB	Plastic Media Blasting
PMC	Polymer-Matrix Composite
PNL	Pacific Northwest Laboratory
POAM	Polar Ozone and Aerosol Monitor
POL	Petroleum, Oil, Lubricants
PP	Pollution Prevention Thrust Area
PTFE	Polytetrafluoroethylene
PTT	Platform Transmitter Terminals
PVD	Physical Vapor Deposition
QA/QC	Quality Assurance/Quality Control
QMP	Quality Management Plan
QSAR	Quantitative Structural Activation Reaction
R&D	Research and Development
RACER	Remedial Action Cost Engineering and Requirements
RAIDS	Remote Atmospheric and Ionospheric Detection System
RASS	Radio Acoustic Sounding System
RBCA	Risk-Based Corrective Action
RCI	Rapid Commercialization Initiative
RCRA	Resource Conservation and Recovery Act
RCW	Red-Cockaded Woodpecker
RDBMS	Relational Database Management System
RDT&E	Research, Development Test & Evaluation
RDX	Hexahydro-1,3,5-trinitro-1,3,5-triazine
REEP	Renewable and Energy Efficiency Planning
RfD	Reference Dose

RMA	Rocky Mountain Arsenal
ROD	Record of Decision
RREL-EPA	Risk Reduction Engineering Laboratory - Environmental Protection Agency
RSKERL	Robert S. Kerr Environmental Research Laboratory
RTDF	Remediation Technologies Development Forum
RTG	Room Temperature Gradiometer
RTV	Room Temperature Vulcanizing
RUSLE	Revised Universal Soil Loss Equation
S&T	Science and Technology
S-O&CS	Smokes, Obscurants & Chemical Simulant Agents
SAB	Scientific Advisory Board
SAE	Society of Automotive Engineers
SAGE	Solvent Alternatives Guide
SALSA	Semi-Arid Land Surface Atmosphere
SANS	Small Angle Neutron Scattering
SAPT	Symmetry Adapted Perturbation Theory
SAR	Structural Activity Relationships
SAR	Synthetic Aperture Radar
SBAA	Sulfuric-Boric Acid Anodize
SBIR	Small Business Innovation Research
SCAMP	Subsurface Cleanup and Mobilization Processes
SCAPS	Site Characterization and Analysis Penetrometer System
SCF	Supercritical Fluid
SCFE	Supercritical Fluid Extraction
SCR	Selective Catalytic Reduction
SCWO	Supercritical Water Oxidation
SDI	Strategic Defense Initiative
SEAM3D	Sequential Electron Acceptor Model in 3D
SEM	Scanning Electron Microscope
SEMP	SERDP Ecosystem Management Project
SERDP	Strategic Environmental Research and Development Program
SERS	Surface Enhanced Raman Sensor
SF	Supercritical Fluid
SFC	Specific Fuel Consumption
SFE	Supercritical Fluid Extraction
SHDS	Solvent Handbook Data System
SIFDT	Selected Ion Flow-Drift Tube
SIMWE	Simulated Water Erosion
SKP	Scanning Kelvin Probe
SMCA	Single Manager for Conventional Ammunition
Sn	Tin
SNAP	Significant New Alternatives Policy
SNL	Sandia National Laboratory

SNRM	Strategic Natural Resources Management
SO_2	Sulfur Dioxide
SODS	Seismic Ordnance Detection System
SOFAR	Deep Sound Conducting Channel
SON	Statement Of Need
SOP	Standard Operating Procedure
SOSUS	Sound Surveillance System
SOTA	State-Of-The-Art
SQUID	Superconducting Quantum Interference Device
SRS	Savannah River Site
SRTC	Savannah River Technology Center
STR	Synthetic Tandem Repeat
SVE	Soil Vapor Extraction
SW	Shallow Water
TACOM	(U.S. Army) Tank-Automotive & Armaments Command
TAMU	Texas A&M University
TAP	Technical Advisory Panel
TARA	DoD Environmental Technology Area Review & Assessment
TCA	Trichloroethane
TCE	Trichloroethylene
TCLP	Toxicity Characteristic Leachate Procedure
TDL	Tunable Diode Laser
TDP	Technology Development Plan
TDS	Total Dissolved Solids
TES	Threatened and Endangered Species
TET	Tetryl
TETAT	Technology Education and Training Advisory Taskforce
Tg	Transition Temperature
TIPPP	Tidewater Interagency Pollution Prevention Program
TIWET	The Institute for Wildlife and Environmental Toxicology
TL	Transmission Loss
TLM	Test Location Manager
TOF-SIMS	Time of Flight Secondary Ion Mass Spectrometry
TNAZ	Tri-Nitro Azetidine
TNB	Trinitrobenzene
TNT	Trinitrotoluene
TPE	Thermoplastic Elastomer
TRI	Toxic Release Inventory
TRU	Transuranic Radioactive Waste
TSVP	Thermal Spray Vitrification Process
TTAWG	Technology Thrust Area Working Group
TV	Trapped Vortex
TVC	Trapped Vortex Combustor

UARS	Unmanned Air Reconnaissance System
UAV	Unmanned Aerospace Vehicle
UB	Ultra Broadband
UFA	Unsaturated Flow Apparatus
UFAL	Ultra-Fine Aluminum
UHC	Unburned Hydrocarbons
UM	University of Minnesota
USACE	United States Army Corps of Engineers
USACERL	U.S. Army Corps of Engineers, Construction Engineering Research Laboratories
USAERDC	U.S. Army Engineer Research and Development Center
USDA	United States Department of Agriculture
USFWS	U.S. Fish and Wildlife Service
USGCRP	U.S. Global Change Research Program
USGS	U.S. Geological Survey
USPED	Unit Stream Power Erosion/Deposition
UST	Underground Storage Tank
UVRS	Ultraviolet Remote Sensing
UWB	Ultra Wide Band
UXO	Unexploded Ordnance
VAAP	Volunteer Army Ammunition Plant
VARTM	Vacuum-Assisted Resin Transfer Molding
VCPI	Visual Cleaning Performance Indicator
VLA	Vertical Line Arrays
VNTR	Variable Number of Tandem Repeats
VOC	Volatile Organic Compound
VPI	Virginia Polytechnic Institute and State University
WASI	Wide-Area Spectral Imaging
WEPP	Water Erosion Prediction Project
WES	U.S. Army Engineer Waterways Experiment Station
WHV	Wildlife Habitat Value Function
WIC	Water-Injection Controller
WR	Water Reducible
WS	Weapon Systems
WWW	World Wide Web
XAS	X-ray Absorption Spectroscopy
XCRIS	X-windows-based Cultural Resource Information System
XPS	X-ray Photo-Electron Spectroscopy
XRD	X-ray Diffraction
XRF	X-ray Fluorescence
XRS	X-ray Spectrometry

YP	Yard Patrol
Zn	Zinc

INDEX